THE YEAR IN SCIENCE

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SCIENCE FOR THE CURIOUS

January/February 2016

100 TOP STORIES OF 2015

PLUTO SHINES

A big year for the little world.

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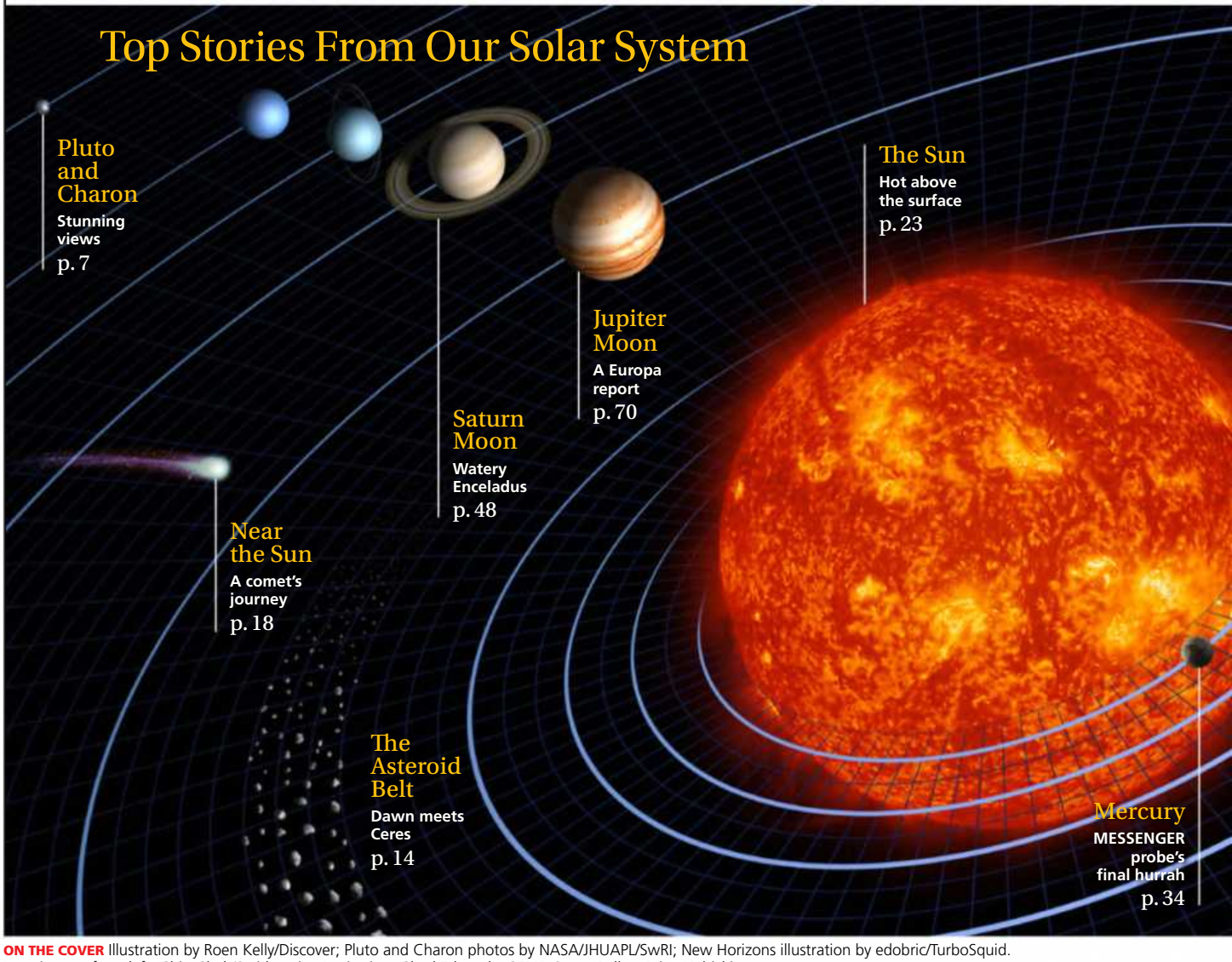

ON THE COVER Illustration by Roen Kelly/Discover; Pluto and Charon photos by NASA/JHUAPL/SwRI; New Horizons illustration by edobric/TurboSquid. Inset images from left: Chip Clark/Smithsonian Institution; Chad Edwards; CERN; Stuart Palley; Brian Kubicki.

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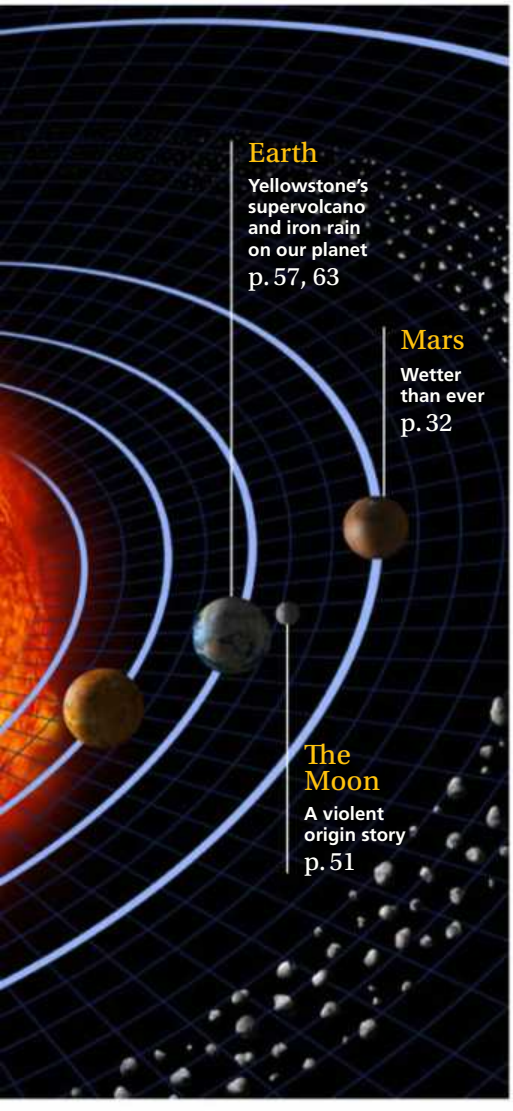
Researchers alter human DNA and spark a heated ethical debate.

BY SHANNON PALUS

. . . and 90 more stories that made 2015 a thrilling year in science.



NASA/JPL

ON THE COVER

Editor's Note

It's here — our giant-size Year in Science issue, featuring the top 100 science stories from 2015, plus our fiery Image of the Year. As usual, we're devoting all of our pages to those stories, but don't worry: Your favorite columns will return next time. Meanwhile, enjoy the issue and be sure to visit **DiscoverMagazine.com/YearInScience** for bonus coverage of our top 100 stories and much more.

Stephen C. George, **EDITOR IN CHIEF**

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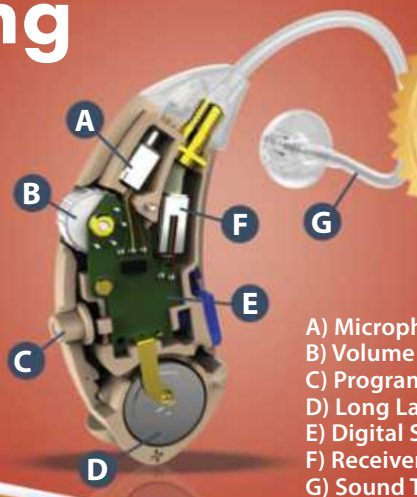

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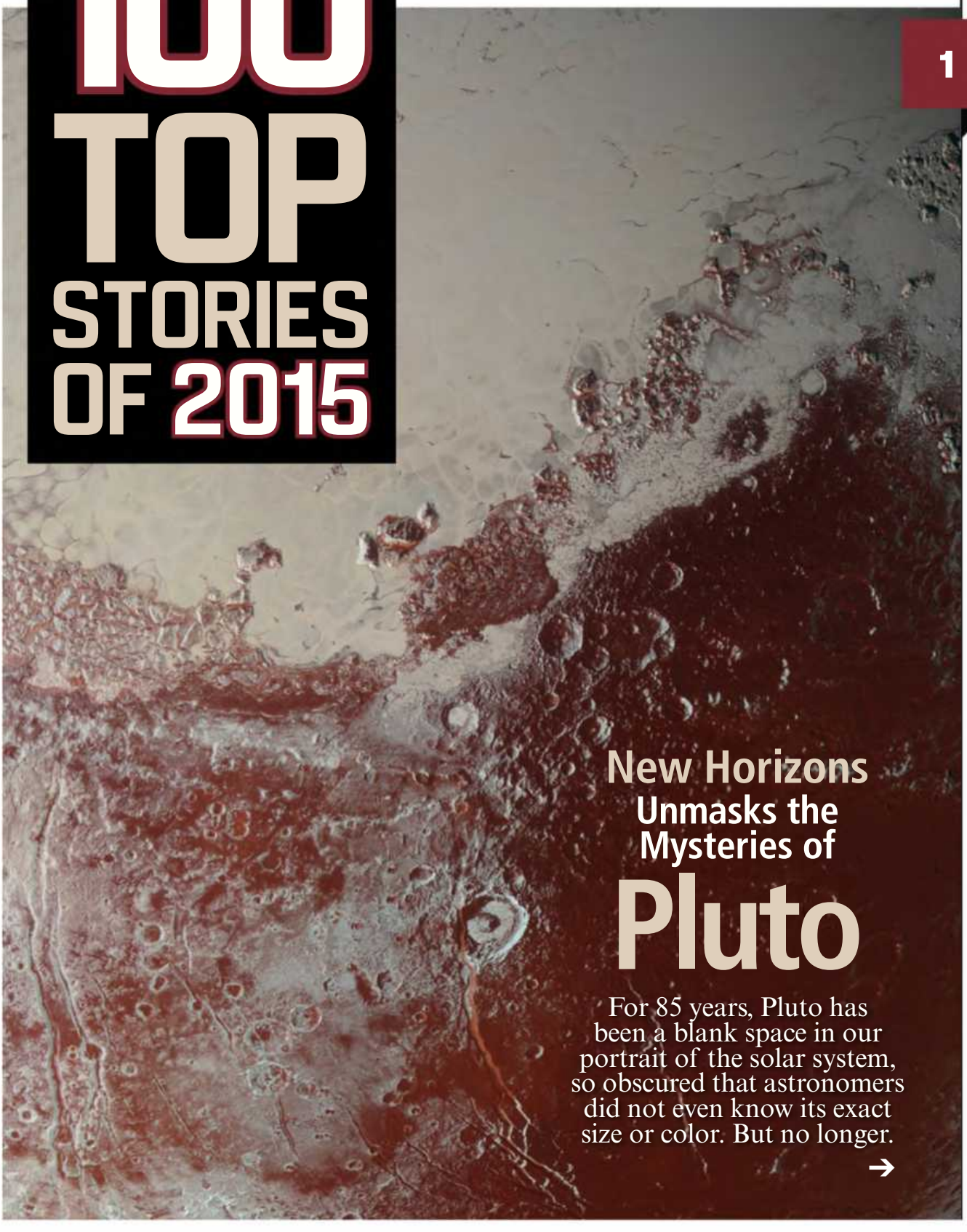
100 TOP STORIES OF 2015

1



New Horizons Unmasks the Mysteries of Pluto

For 85 years, Pluto has been a blank space in our portrait of the solar system, so obscured that astronomers did not even know its exact size or color. But no longer.

→

NASA/JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY/SOUTHWEST RESEARCH INSTITUTE

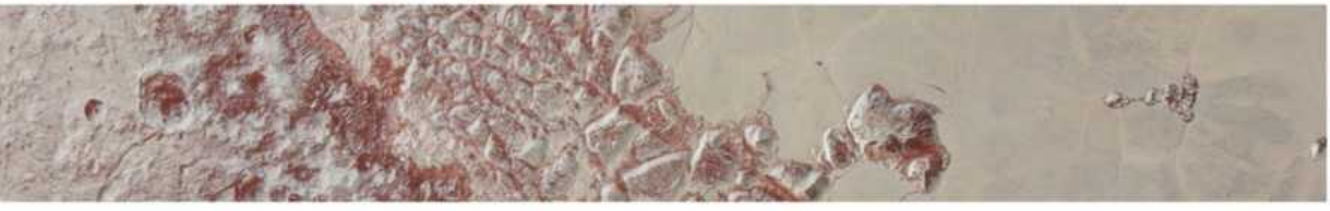
Above: The heart-shaped Tombaugh Regio stands out in this portrait of Pluto and its largest moon, Charon. (The distance between them is not shown to scale.) Far left: A 220-mile-wide view of Pluto's surface shows ancient craters, smooth younger terrain and a field of aligned ridges, possibly dunes. Left: Members of the New Horizons team, including Principal Investigator Alan Stern (center), react to new images from the probe's July 14 flyby.

ALL PLUTO IMAGES: NASA/JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY/SOUTHWEST RESEARCH INSTITUTE. GROUP PHOTO: BILL INGALLS/NASA

On July 14, NASA's New Horizons probe flew just 7,750 miles past Pluto's surface and began radioing back detailed pictures. The sudden unveiling has revealed a complex and inexplicably varied landscape. "It's a total surprise," said mission leader Alan Stern as he pondered the images. "If an artist had painted this Pluto before our flyby, I probably would've called it over the top."

Some areas of Pluto appear dark and heavily cratered, indicating extreme age. Their coloration may come from frozen methane irradiated by the sun and converted into tarlike compounds known as tholins, notes Will Grundy of Lowell Observatory. The whole globe evidently has been painted ruddy brown by a thin coating of such chemicals, prompting New Horizons scientists to dub it "the other red planet." Right next to Pluto's ancient terrain are utterly different landforms, including rippled fields — dunes, possibly — and craggy, 11,000-foot mountains. Those peaks must be composed of water ice, Stern explains, because it is the only likely surface material strong enough to support them. (Water is as hard as granite at Pluto's surface temperature of minus 390 degrees Fahrenheit.)

From there, the findings get even stranger: Some material appears to flow down from the mountains. Most likely it is nitrogen ice, accumulated as gases in Pluto's atmosphere freeze during its 60-year-long winter. Beyond the nitrogen glaciers are extensive plains, devoid of the expected craters and marked instead by polygonal depressions where relatively warm material may be seeping up from below. Such fresh-looking regions indicate recent — possibly ongoing — geologic



Right: Round and strangely textured mountains rise near Pluto's day-night border in this 330-mile-wide view. Far right: A departing shot from New Horizons captures Pluto's hazy atmosphere. Below: Another view of Pluto's diverse landscape, captured just before closest approach, reveals features as small as 270 yards across. Bottom: Icy mountains up to 11,000 feet high border the smooth Sputnik Planum, the left "lobe" of Tombaugh Regio's heart.

activity. Even more surprising, New Horizons images show that Pluto's moon Charon, about half the size of the 1,473-mile-wide world, is also dynamic, with long fractures, smooth lowlands and odd, isolated massifs.

The new views of Pluto and Charon consolidate a revolutionary idea brewing since the Voyager missions of the 1970s. Before then, scientists had broadly assumed that small bodies in the outer solar system must be cold and inert. In reality, space probes showed that the moons of the outer planets are wildly active, from the sulfur volcanoes of Jupiter's Io to the dusty geysers of Neptune's Triton. The fallback assumption was that moons are special, energized by the giant worlds they orbit, but that surely small standalone bodies like Pluto must be deadly dull. New Horizons has now blown away that bit of planetary chauvinism as well, and replaced it with a captivating mystery: What is the energy source driving all the activity?

One idea is that oceans deep inside these worlds hold residual heat for billions of years. Whatever the cause, the effect is probably extremely common. Pluto and Charon have hundreds of thousands of cousins, collectively filling a zone called the Kuiper Belt. It's a good bet that many of those little-understood objects are active, too.

New Horizons' mission is still far from over. In January 2019, it is scheduled to visit another, much smaller Kuiper Belt object known as 2014 MU69. Meanwhile, the probe will continue sending data from the Pluto flyby through the end of 2016. The results should fill in many more brushstrokes — not just for Pluto's portrait, but also for the entire process of planetary formation.

— COREY S. POWELL

2

Bones of at least 15 individuals from a South African cave represent the largest early hominin find ever discovered.

Homo naledi and the Chamber of Secrets

Deep underground, beyond a 39-foot vertical shaft narrowing to 8 inches in some spots, tantalizing clues of humanity's earliest origins are whispering up from the darkness. Here, in the Dinaledi Chamber of South Africa's Rising Star cave system, researchers have found a spectacular assemblage of fossils they say belongs to a new human species: *Homo naledi.*

In September, University of the Witwatersrand paleoanthropologist Lee Berger and his team described the fossils — discovered by spelunkers in 2013 — in the journal *eLife*. Media hoopla surrounding speculation about *H. naledi*'s behavior distracted attention from what made the discovery so scientifically important: the unprecedented quantity of bones. Ancient hominin fossils are rare, and those from early members of our own genus, *Homo*, are rarer still. So it is all the more astonishing that Berger's team recovered more than 1,500 fossils, from 15 individuals, including a fully articulated hand — the first ever found for early *Homo*.

H. naledi has a mix of primitive and modern anatomy, with an upper body suited for climbing trees and a lower body, particularly its feet, capable of walking long distances. The stunner is *H. naledi*'s cranium: It's shaped like the later, more advanced *Homo erectus*, but — with less than half the volume of our own — is tiny for its 5-foot-tall body.

Berger's team suggests that these primitive humans may have been put in the cave by their kin in an act of "deliberate

JOHN HAWKS/UNIVERSITY OF WISCONSIN-MADISON

body disposal." Such behavior would be incredible because only modern humans and Neanderthals, our closest relatives, are believed to have buried their dead.

Compounding the controversy around the team's claim is not knowing how old *H. naledi* is. The age of a hominin fossil is typically determined by using a proxy — more easily dateable matter, such as bones of now-extinct animals with known timespans — deposited around the same time as the bones. In the case of *H. naledi*, this material doesn't seem to exist.

The team will attempt to establish the fossils' age through alternative methods in the coming months. The information is crucial for understanding whether *H. naledi* is a primitive human displaying a behavior otherwise unknown until much later in hominin evolution, or a relatively modern human with a primitive anatomy that challenges conventional ideas about how our genus developed.

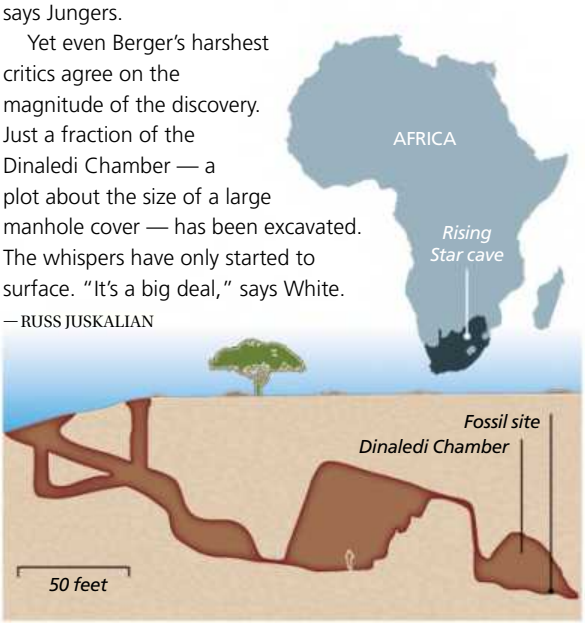
Regardless of the age, Berger said earlier this year, before publishing the *H. naledi* discovery, the fossils will force paleoanthropology to rethink long-held theories about human evolution.

Not everyone agrees. Tim White, a paleoanthropologist not connected to the project, says the findings were published too early, with too much left unknown — including the age of the fossils and whether concrete evidence for the intentional placement of the dead exists. He says this rushed approach, which came amid a media frenzy, risked putting entertainment and excitement ahead of the less glamorous slog of more deliberate science.

Others, like William Jungers, a paleoanthropologist at Stony Brook University, say there isn't enough evidence to confirm that *H. naledi* is necessarily a new species. "It could even be an early, regional representative of *Homo erectus*," says Jungers.

Yet even Berger's harshest critics agree on the magnitude of the discovery. Just a fraction of the Dinaledi Chamber — a plot about the size of a large manhole cover — has been excavated. The whispers have only started to surface. "It's a big deal," says White.

— RUSS JUSKALIAN



A cross section of the Rising Star cave system shows the difficult, often nearly impassable route to the fossil trove.

LEFT: CAVES BY JAY SMITH, MAP BY STEFAN ALFONSO/ISTOCK AND DAN BISHOP/DISCOVER. RIGHT: RAFAL CICHAWA/ISTOCK

3

Cradle of Civilization in Peril

Militants wage war on the cultural heritage of an entire region.

Much of Syria's millennia-old city Palmyra, including its Arch of Triumph, was destroyed in 2015 by the so-called Islamic State.

In the mid-13th century, a Mongol invasion cut a wide swath of cultural ruin through the Middle East, including the destruction of the great library of Baghdad. It took the region centuries to recover. Today, many Iraqi and Syrian archaeologists evoke this infamous chapter in medieval history to convey some sense of the devastation wrought by the so-called Islamic State (ISIL), along with the continued brutality of more than four years of civil war in Syria.

While all the key belligerents in the conflict regularly commit cultural property crimes, ISIL stands out as the most brazen and egregious. Its militants expanded the targeting of cultural heritage in 2015 to ratchet up sectarian tensions, fund terrorism and promote their global franchise.

ISIL mainly targets Muslim architecture and monuments for destruction, and it sells looted antiquities and other portable cultural property for funding. Only occasionally do fighters destroy pre-Islamic material for the cameras: In the first months of 2015, ISIL militants overran the Mosul Museum, smashing many of the collection's artifacts, and took bulldozers and sledgehammers to Iraq's fabled first millennium B.C. cities of Nineveh, Nimrud and Hatra, a UNESCO World Heritage site. In April, UNESCO Director General Irina Bokova accused

ISIL of war crimes for these and other acts of destruction. The extremists continued their campaign in August with the destruction of important sites in the ancient desert oasis city of Palmyra, another World Heritage site.

Some might ask, "Why should we fret about 'old stones and bones' amid the human suffering of this conflict?" We do not face either-or decisions between saving lives or culture: The two are inextricably linked. By protecting heritage, we defend cultural identity. Radical extremists understand the power of heritage — they fear and loathe it, hence their obsession with pulverizing symbols of resistance and diversity.

At the same time, cultural property protection undercuts terrorist financing. Beneath its thin ideological veneer, ISIL operates as an organized crime enterprise. As with other transnational criminal groups, antiquities crime provides a reliable and lucrative source of revenue and means of money laundering. While ISIL talks of destroying "ancient idols," in truth many of these artifacts are pouring out of the conflict zone for sale on the black market.

ISIL is adept at fusing global jihad, cultural cleansing and cultural property crime. Left unchecked, radical extremists will eradicate the evidence of more than 10,000 years of human achievement in Syria and Iraq, and the problem is spreading. With each looted archaeological site, robbed museum, exploded monument or burned archive, we lose data on the world's earliest-known agriculture, settled communities, organized religions, state-level polities, writing systems and great empires. Extremists are also stealing the future by destroying cultural assets vital to the tourist sector and by degrading educational and cultural infrastructure.

Syrian and Iraqi cultural heritage experts continue to risk their lives daily to document war crimes and to save our shared cultural patrimony. In August, ISIL militants beheaded archaeologist Khaled al-Asaad, who served as Palmyra's chief of antiquities for half a century. Asaad had helped move many artifacts to safety before ISIL seized control of the site in May. According to media reports, he was killed because he refused to divulge their location.

From verifying reports of destruction with satellite imagery to monitoring the illegal antiquities market, more than 45 international organizations are involved in the effort to preserve the rich legacy of this region, the Cradle of Civilization. As the poet John Donne observed, "No man is an island, entire of itself; every man is a piece of the continent, a part of the main."

— MICHAEL DANTI, ACADEMIC DIRECTOR OF THE AMERICAN SCHOOLS OF ORIENTAL RESEARCH CULTURAL HERITAGE INITIATIVES

Climate at the Crossroads

In the hottest year yet, nations vow to kick the carbon habit.

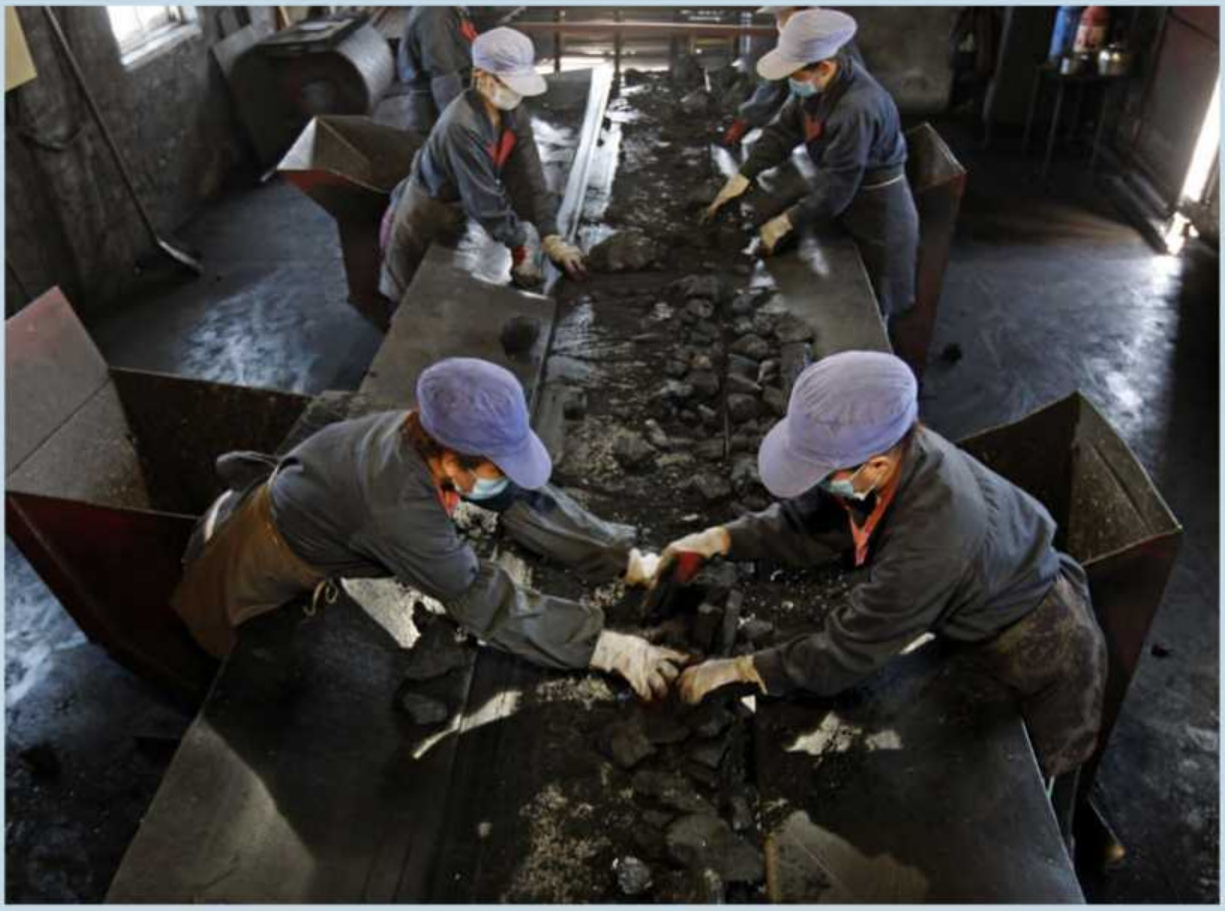
Renewable sources, such as these wind and solar arrays near Palm Springs, Calif., can help nations meet emission targets.

NIK WHEELER/CORBIS

From a climate change perspective, 2015 had all the elements of a good drama: suspense, a surprise twist and a (somewhat) happy ending. It turned out to be the hottest year on record, but ended with new hope for turning down the thermostat: In December, nations are expected to enter into negotiations for a plan to cut greenhouse gas emissions. Throughout the year, a series of scientific revelations underscored its necessity — and overturned some long-standing assumptions.

Two reports, published in February and July, upended the widespread belief that warming had stalled the past 15 years. They revealed that Earth had continued warming as quickly as ever — shifts in ocean circulation had simply cloaked this trend by pulling some extra heat into deep waters for a few years. "This year will be the warmest — it's so far ahead of any other year," Phil Jones, a climatologist at the University of East Anglia in England, said in July. He predicted that by year's end, the average global temperature would exceed the previous record by 0.2 degrees Fahrenheit.

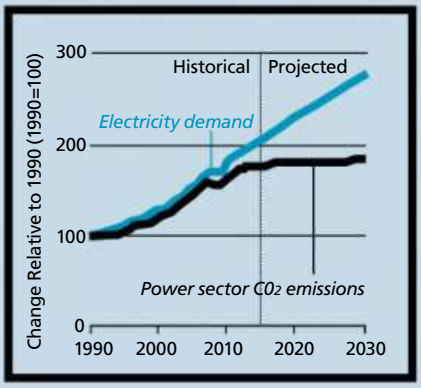
Against this gloomy backdrop, large nations vowed to curb their carbon habit. In anticipation of the U.N. Climate Change Conference in Paris in December, the United States pledged that by 2025 it would cut greenhouse gas emissions by 26 to 28 percent below 2005 levels; the European Union committed to a 40 percent reduction by 2030; and



Laborers process coal at a factory in eastern China. New power plants in developing countries will keep demand high for decades.

China — the world's biggest emitter — agreed to begin lowering its emissions by 2030. The U.S. also announced that, for the first time, it would regulate carbon pollution from power plants.

Still, an ominous trend threatens to undermine this progress: Global reliance on coal, the highest-carbon fuel of all, is rapidly growing. Another July study found that cheap coal exports from the U.S., Australia and elsewhere are driving a "coal renaissance" in dozens of developing countries. Those nations are expected to build hundreds of new coal-fired power plants by 2030. Once up and running, "those coal capacities will stand there for the next 30 to 40 years," contributing billions of tons of carbon emissions, says Jan Steckel, an economist at the Potsdam Institute for Climate Impact Research in Germany, who led the study.



If nations hit their reduction targets, global carbon dioxide emissions would level off, even as electricity demand continues to rise.

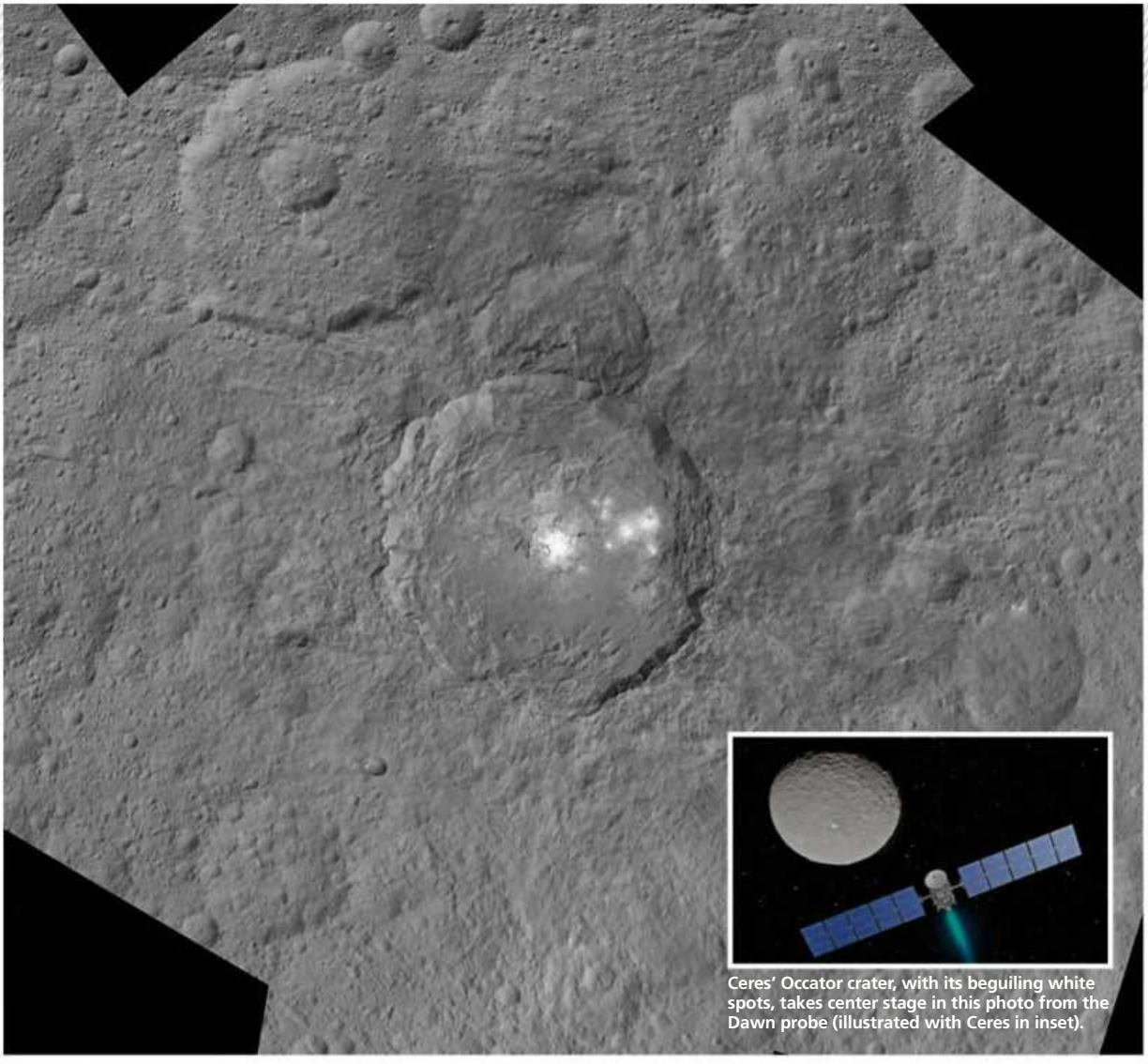
If these economies could be persuaded to shift to renewable energy, that scenario could be averted, but the window of opportunity is closing, says Steckel. Negotiators at the Paris talks, which had not begun by press time, hope to figure out how to make that transition to renewables more affordable.

The benefits of making these hard choices are clear. Some researchers say cutting carbon emissions enough to limit warming to 3.6 F (2 degrees Celsius) above pre-industrial levels could avert the worst impacts of climate change. The Amazon forest, which stores vast amounts of carbon, would survive, and according to a study published in September, staying within this threshold could stop sea level rise at 5 or 10 feet. While much of Florida would be sacrificed, many other coastal areas would remain intact.

Meeting this goal would require capping humanity's cumulative carbon emissions at about a trillion tons, and we've already burned through about two-thirds of that "allowed" carbon budget. We must choose wisely how we spend the rest. —DOUGLAS FOX

TOP: ZHENGYI XIE/CPRESSPHOTO/CORBIS. BOTTOM: OECD/IEA 2015, FROM WORLD ENERGY OUTLOOK 2015 SPECIAL BRIEFING FOR COP21

5



Ceres' Occator crater, with its beguiling white spots, takes center stage in this photo from the Dawn probe (illustrated with Ceres in inset).

When Dawn Met Ceres

Pluto wasn't the only dwarf planet to host a guest this year. In March, four months before New Horizons made it to Pluto, NASA's Dawn probe entered Ceres' orbit, becoming the first to see a dwarf planet up close.

Dawn launched in 2007 and visited asteroid Vesta first, keeping that rock company for 14 months before flitting off to its final destination: Ceres, the largest body in the asteroid belt between Mars and Jupiter. Hovering around Ceres like a nosy paparazzo, Dawn has been snapping photos and maneuvering ever closer since March. It was expected to reach its closest and permanent orbit, 230 miles above the surface, in December.

Ceres is so big, nearly 600 miles across, that astronomers considered it a regular planet for almost 50 years after its 1801 discovery. That size means gravity has pulled Ceres into a sphere, with a core of rock, an icy coating and perhaps an ocean of liquid water locked between. But Ceres remained fuzzy from afar, until Dawn revealed a fascinating world with miles-high mountains and miles-deep craters. Ceres' surface is covered by landslides and plump with ice. The diminutive planet is more dynamic than scientists expected.

"Exploring a new world, even virtually, is a thrill," says Carol Raymond, Dawn's deputy principal investigator. The greatest thrill so far came from a crater named Occator, 2 miles deep. From inside, a cluster of bright spots stares out. Scientists believe they are splotches of salt, magnesium sulfate, perhaps left by saline water that bubbled — or maybe still bubbles — up from the underground ocean and splashes over the terrain.

In fact, the water on our planet likely came from pre-planets much like Ceres. "Bodies like Vesta and Ceres were the building blocks of the solar system, like Legos," says Christopher Russell, Dawn's principal investigator. "Give me a bunch of corner pieces, and I can build something that looks like a house. Give me a bunch of Vestas, and I can make a dry Earth with a rocky core. Add a few Ceres, and I can fill the oceans and lakes and streams." —SARAH SCOLES

NASA/JPL-CALTECH/UCLA/MPS/DLR/IDA. INSET: NASA/JPL-CALTECH/UCLA/MPS/DLR/IDA/ERNIE MASTROIANNI/DISCOVER

Tool Time's New Start Date

Researcher Sonia Harmand holds one of several stone tools found at the Lomekwi site near Kenya's Lake Turkana; at 3.3 million years old, they are the earliest tools ever found.

The road almost not taken led to the discovery of a lifetime. In 2011 archaeologists Sonia Harmand and Jason Lewis of Stony Brook University and colleagues took a wrong turn as they followed a creek bed, surveying sites around Lomekwi, near Kenya's Lake Turkana. A team member spotted stone tools eroding from sediment laid down 3.3 million years ago, making them the oldest ever found.

Up to 8 inches long, these tools are larger, heavier and less refined than those of the 2.6-million-year-old Oldowan type, the previous record-holder of the oldest tool title. Like Oldowan tools, the Lomekwian tools were clearly modified with intention, Harmand says. The maker mainly used a two-handed technique, holding a core on another large rock, or anvil, and hitting it with a hammer stone to release sharp flakes.

Researchers found the Lomekwi site by chance after taking a wrong turn along an eroded creek bed.

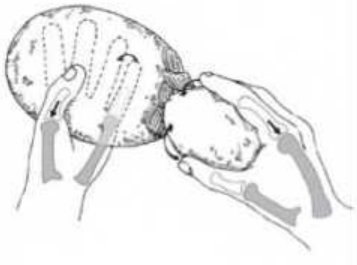
Until now, stone tool knapping and the abstract thought it requires have been credited to the genus *Homo*, beginning with *Homo habilis*, the presumed originator of the Oldowan style. But the Lomekwian toolkit, reported in *Nature* in May, predates *H. habilis* by half a million years. So far, all the candidates for making the Lomekwian tools are pre-*Homo* species, including *Australopithecus afarensis* of Lucy fame, and *Kenyanthropus platyops*, discovered in 1998 near the Lomekwi site. Says Lewis, "If it's a non-*Homo* species, that's a big game changer." — HILLARY WATERMAN

Did our hand strength and dexterity evolve with earlier australopiths?

Getting a Grip

To learn more about the evolution of the "power squeeze" — the grip we use to hold a hammer — University of Kent anthropologist Matt Skinner compared hand and wrist bones from living and extinct hominids using 3-D X-ray technology. Human hand bones showed increased density in certain key spots associated with toolmaking.

In research reported in *Science* in January, Skinner found the same modifications in corresponding bones from *Australopithecus africanus*, possibly a direct ancestor of the *Homo* genus, which suggests that toolmaking was an earlier adaptation than previously thought. Could this help us identify the Lomekwian toolmakers? "The main point," says Skinner, "is that there was no *Homo* around [3.3 million years ago], so it would either need to be *Australopithecus* or *Kenyanthropus* who made those tools." — HW



Toolmaking — no longer seen as uniquely human — requires using the thumb and fingers in opposition.

7

Ebola Aftermath

The Ebola outbreak gripped the world in 2014, infecting more than 24,000 people and claiming over 11,000 lives. In 2015, the epidemic was ongoing in parts of Sierra Leone, Liberia and Guinea. *Discover* talked with three scientists involved in the worst Ebola outbreak in history, about their roles and the promising vaccines that may ultimately vanquish the disease. —LINDA MARSA

After surviving Ebola but losing 21 relatives in Sierra Leone's outbreak, Victoria Yillia (above) looked for renewal with the birth of her son, Barnabas, in August 2015. He died just weeks later of an unrelated infection. After another burial, workers (below) walk past graves outside Monrovia, Liberia.

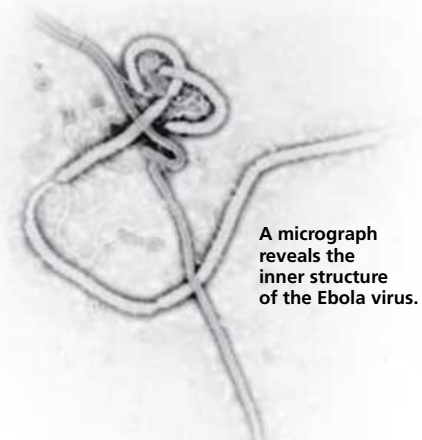
Alexandre Delamou

Chief of research, National Centre for Training and Research, Maferinyah, Guinea

Ebola's lasting legacy may be in maternal and child health: Public health officials worry that deaths during childbirth and from preventable childhood diseases like measles could escalate into the tens of thousands. Delamou talks about why the collateral damage triggered by the epidemic could turn out to be even more lethal than the outbreak itself.

Delamou: There have been a lot of efforts to improve access to maternal health in Guinea, Liberia and Sierra Leone. But one of the impacts of Ebola is a decrease in hospital attendance because there were a lot of infections among health professionals. And the outbreak is not over — we had 10 to 12 new cases a week [until recently]. So people still don't feel safe, and they continue thinking that hospitals are a place where you can get Ebola. Multiple Ebola cases occurred in rural communities, and health care providers left those areas to come to the cities, and most did not return. So now, when women in rural areas choose to deliver at home, if they have complications, there's no one who can take care of them, and they're more likely to die.

Children's health is connected to their mothers' health. Because pregnant women won't come to the hospital to have their babies delivered, it is unlikely she will bring her newborn in later for immunizations. There is now a measles outbreak in this country, which is a direct consequence of the lack of usual immunization services, and there have already been some deaths.



A micrograph reveals the inner structure of the Ebola virus.

FROM TOP: ITM ANTWERP; SUNDAY ALAMBA/AP PHOTO/CORBIS; ABBAS DULLEH/AP PHOTO/CORBIS; CDC/DR. FREDERICK A. MURPHY

Joanne Liu

President, MSF International, Geneva, Switzerland

The medical aid group Doctors Without Borders (Médecins Sans Frontières, or MSF) dispatched more than 700 doctors, health care professionals and relief workers to ground zero, treating about 35 percent of all Ebola patients, starting in March 2014. Within MSF, 28 of its colleagues became infected, 14 of whom died, and the aid group cared for more than 2,600 patients who later died. MSF was among the first to sound the alarms about the Ebola outbreak.

Liu: Ebola spun out of control because of a lack of political leadership — the world stood aside while Ebola tore through western Africa. Everyone missed Ebola, but when we said it was out of control, we were [accused of] being alarmist. It was only when an American got sick in August of 2014 that the world woke up and took action to stop Ebola from coming to their countries.

But it was too little, too late, and thousands were already dead or dying. When I visited western Africa [that] August, I saw how local people were completely overwhelmed by the situation. We didn't have enough room for all the patients, there was no place for them to lie down, and we were completely limited in the care we were providing. This is the first time in all of our history that MSF built crematoriums — we had too many dead bodies.

This was the first outbreak that spread from rural to urban areas. Normally, outbreaks last between eight and 12 weeks, but this has lasted 17 months and is still ongoing. There is a triumphant narrative that it's over when it is absolutely not. We are kidding ourselves. This outbreak started with one case, and it could flare up again.

Initially, we told people it's a deadly disease and we have no cure, so essentially we're telling them, "Come and die in an Ebola center." We need to change that because if these people come in earlier, they have a better chance to pull through and not infect their loved ones. We know what to do because it's like HIV and AIDS two decades ago — it was a death sentence, and people hid from it. But today it is not a death sentence, and we need to apply what we learned from fighting that epidemic.

Thomas Geisbert

Virologist, University of Texas Medical Branch, Galveston

Human safety tests of two vaccines began in the summer of 2014, after the prototypes languished in labs for nearly a decade because Ebola wasn't enough of a threat to attract Big Pharma. But one of them — VSV-ZEBOV, in which the Ebola protein is spliced inside of a live vesicular stomatitis virus normally found in cattle — proved 100 percent effective in a preliminary test of more than 4,000 people in Guinea this past summer. Geisbert helped devise the VSV-ZEBOV vaccine and also worked on an inhaled version of the vaccine that immunized monkeys earlier in 2015.

Geisbert: After 9/11, there was a lot of concern that Ebola could be used as a bioterror agent, and the National Institutes of Health put a lot of money into biodefense. But there wasn't any money for product development or the financial incentive for Big Pharma to get involved because who were you going to sell your drug to? Still, we made tremendous progress as a field, but everything just sat there until this outbreak. I felt a real sense of frustration watching this outbreak because we had something sitting on the shelf that might have saved lives. But the silver lining is that we now have the public's attention.

The VSV vaccine is extremely robust and has tremendous potential to be used to control an outbreak and contain its spread rather than to vaccinate large populations. To contain, manage and control an outbreak in Africa, you need a vaccine that requires just one injection and that works quickly. The VSV vaccine works fast, within seven to 10 days. It was shown to protect up to 50 percent of primates after exposure but before they show symptoms.

Consequently, this vaccine has a great chance of combatting an outbreak in the context of ring vaccinations, where you give the vaccine only to people in close contact with infected patients. That strategy can be used to break the chains of transmission and reduce the number of cases. It can also be used with first responders and health care workers who need to be protected really quickly.

The Ebola vaccine VSV-ZEBOV is prepared for injection (top) during clinical trials. The vaccine can be stored in the field for up to five days at minus 76 degrees Fahrenheit (above). A sign in Monrovia (below) urges residents to take action against the virus.

CLOCKWISE FROM TOP LEFT: FERNANDO CALERO/MSF; THE UNIVERSITY OF TEXAS MEDICAL BRANCH AT GALVESTON; SEAN HAWKEY/WORLD HEALTH ORGANIZATION (2); ZOOM DOSSO/AFP/GETTY IMAGES

8

Psychology's Inner Demons

It was a group project of staggering proportions. University of Virginia psychology professor Brian Nosek and his colleagues at the nonprofit Center for Open Science got help from over 350 scientists to repeat 100 high-profile psychology experiments published in 2008 — the largest replication study to date. In August, they announced the results in *Science*, forcing psychologists to face some hard truths about the reliability of their field's studies.

The project is a response to the so-called "reproducibility crisis," a growing concern that many published studies may not hold up to repeat testing. The problem affects other sciences, but several high-profile failures to reproduce important psychology findings have made it a particular concern.

Researchers not involved in the initial studies contacted the original authors to get feedback on their protocols; in most cases, the original researchers helped with study designs and strategies. Despite this thoroughness, while 97 of the original studies reported significant results, only 35 of the replications reported the same. And even then, the effect size (a measurement of how strong a finding is) was smaller — on average, less than half the original size. So even when Nosek's team ended up with significant results, those results weren't as strong as the initial reports claimed they were.

The replications are not definitive, Nosek says: "No study provides perfect evidence for or against any finding, and that also applies to the original [studies]." The replication simply adds information about the phenomenon under study, he says.

But it does mean that psychologists are starting to learn more about how to make their experiments more rigorous. "What this paper can help us do is accept that this is a problem so we can go about finding ways to fix it," says Dorothy Bishop, a psychologist at the University of Oxford and a leading voice on psychology's reproducibility issues. The problem won't be solved overnight, but this study is a step in the right direction.

—CHRISTIE ASCHWANDEN

Brian Nosek and his team replicated 100 high-profile psychology studies. The findings highlight the field's need for more rigorous experiments.

9



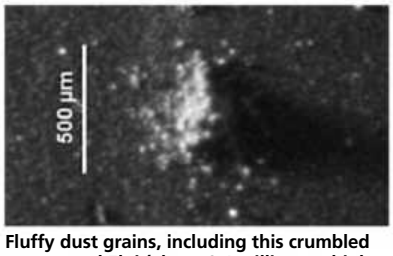

Rosetta Reveals the Heart of a Comet

Rosetta became the first spacecraft to orbit a space iceball when it reached Comet 67P/Churyumov-Gerasimenko in 2014. This year we learned even more about the ancient object and, in turn, the solar system.

"Comets have been stored far from the sun in a deep freeze," says Rosetta principal investigator Alan Stern of the Southwest Research Institute. "They represent samples of the original material out of which planets were formed."

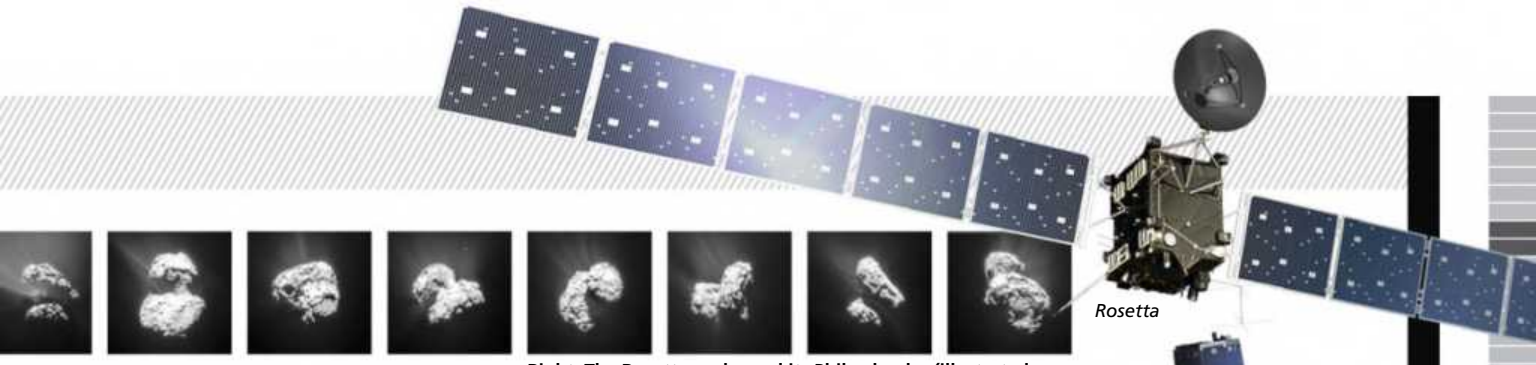
Rosetta's been telling the comet's secrets ever since its May 2014 arrival, starting with its rubber duck-shaped body, 4.1 miles long with a head 1.6 miles wide. Fluffy dust up to 16 feet thick coats the comet's surface and acts like sunscreen, protecting the vulnerable ice from the sun's heat. This has kept 67P together despite its millions of close encounters with the sun, around which it orbits every 6.6 years.

But as it approaches the sun, the comet does release into space some dust and gas, which form its tails.



Fluffy dust grains, including this crumbled one named Eloi (about 0.1 millimeter high and half a millimeter across), likely built up since the comet's last close pass to the sun.

FAR LEFT: STEPHEN VOSS



Right: The Rosetta probe and its Philae lander (illustrated here) have brought us the best views of a comet ever. Above: Comet 67P/Churyumov-Gerasimenko from multiple angles. Below: A close-up of the comet's bifurcated form.

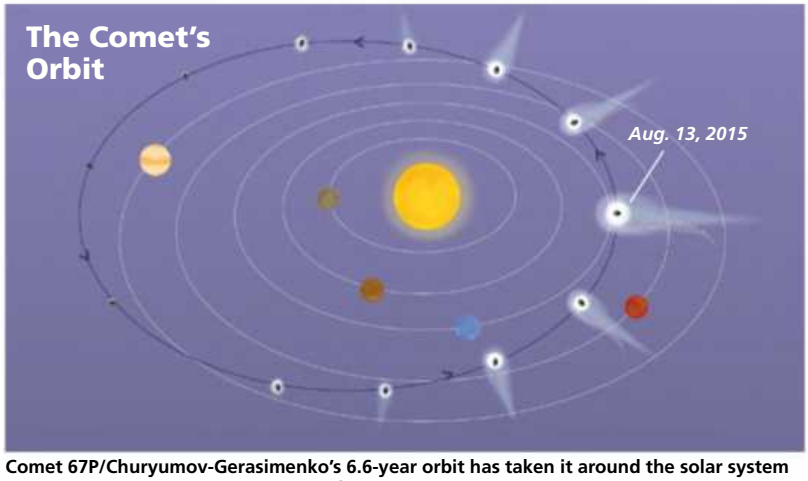
Astronomers were surprised to see molecular oxygen, the kind humans breathe, blasting from the comet. The comet also released about 24 times as much water as oxygen, as well as a great deal of carbon monoxide and carbon dioxide. The liberated dust contains many organic molecules, showing that comets may have seeded our planet with the chemistry that life needs to thrive. The probe further revealed the comet is less than half as dense as water and three-quarters empty space.

Scientists had also long suspected that comets' crashing into Earth had given our planet its water stores, but Rosetta found otherwise. The water on Comet 67P has more neutrons than earthly water, suggesting different origins.

To get a closer look, in November 2014 Rosetta deployed its lander, Philae. Instead of landing smoothly on the surface, the solar-fueled lander bounced and rolled away, coming to rest in the shade where it soon lost power. While scientists did revive Philae in June 2015 and confirmed that all its instruments had a pulse, they couldn't get those instruments to actually do anything. It went silent a week later.

During its brief but productive life, Philae detected 16 organic molecules, confirming the orbiter's findings and showing that the chemicals of life can form and survive in space. The lander also found the comet has no magnetic field, meaning magnetism doesn't affect how the early solar system's building blocks came together, contrary to several models.

Just after Philae's momentary resurrection, 67P roared to life. On July 29, the comet released a huge jet of gas and dust moving at 22 mph. On Aug. 13, the comet reached perihelion — its closest approach to the sun — and released two bathtubs' worth of water every second. Engineers moved Rosetta farther away from the comet to protect it from the deluge and dust.



Comet 67P/Churyumov-Gerasimenko's 6.6-year orbit has taken it around the solar system countless times, but Rosetta joined it for its most recent close pass to the sun in August.

Since its close encounter, 67P has been spewing less and cooling off, getting ready to return to its cosmic freezer, with Rosetta in tow. The probe will continue to watch the show until its mission ends in September 2016, when scientists will likely send it to rest on the comet's surface. — SARAH SCOLES

COMET: ESA/ROSETTA/NAVCAM. SPACECRAFT: ESA/ATG MEDIALAB. COMET DUST: ESA/ROSETTA/MPS FOR COSIMA TEAM. MAP: ESA

10

The Ethics of Editing Human Embryos

Imagine if genetic diseases could be removed from the very biological code of our species — a future in which the likes of hemophilia, cystic fibrosis or dozens of other afflictions are simply edited out of human embryos.

In April online in the journal *Protein and Cell*, a team of Chinese scientists reported the first documented experiment to do just that.

The researchers attempted to quash an inherited, potentially fatal blood disorder by injecting 86 non-viable human embryos with the gene-editing system CRISPR/Cas9. In recent years, CRISPR has emerged as a game-changing tool in biology, allowing researchers to tweak an organism's DNA with unprecedented ease. Based on a defense mechanism in the immune system of bacteria that hunts and destroys invading viruses, CRISPR can locate and replace specific genes.

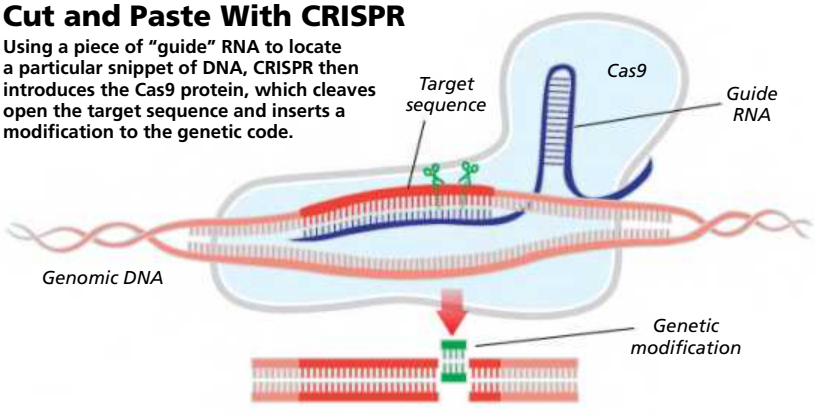
In the human embryo experiment, the researchers used it to delete a faulty gene and replace it with one that produces normal blood cells. But the editing worked for only four of the embryos and created numerous unintentional mutations.

Those accidental mutations illustrate the concerns some scientists have about using the tool in humans. Earlier in the year, when the Chinese team's experiment was still a rumor, 18 researchers co-authored a letter in *Science* that called for the community to address the ethical questions and potential hazards of using CRISPR in humans. Until we can wield CRISPR more precisely and understand the implications of its use more fully, said the scientists, it should not be used on humans.

Despite the concerns, in September researchers at the Francis Crick Institute in London applied to the United Kingdom's governing authority on fertility research for permission to use CRISPR on human embryos. The need for clear guidelines has spurred the organization of an international summit on human gene editing. As of this writing, it was scheduled for early December in Washington, D.C. — SHANNON PALUS

Cut and Paste With CRISPR

Using a piece of "guide" RNA to locate a particular snippet of DNA, CRISPR then introduces the Cas9 protein, which cleaves open the target sequence and inserts a modification to the genetic code.



11

Splice of Life

The door to creating designer species blew open in March when scientists announced the first successful demonstration of genetically altered animals passing their tweaked DNA automatically to their progeny.

Normally, any mutation has a 50-50 chance of being passed on because half the genes come from mom, the other half from dad. But biologists at the University of California, San Diego, found a way to ensure a fruit fly offspring inherited a genetic splice from a parent 95 percent of the time, according to the paper in *Science*.

The team used the CRISPR genetic engineering technique to ensure that a mutation they inserted into one copy of the fly's chromosome spread automatically to the other copy, according to Valentino Gantz, a co-author of the study. It's a process he calls mutagenic chain reaction, or MCR.

MCR could transform entire populations of sexually reproducing species within months, making it a powerful new tool for research. The technique could also be used to tinker with plant pests or mosquitoes so they don't spread lethal diseases, such as malaria. — LINDA MARSA

Researchers introduced a mutation — lighter coloration on the flies' left side — to test a new way of altering DNA.

TOP: ALISON MACKEY/DISCOVER. BOTTOM: VALENTINO GANTZ/UC SAN DIEGO

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12

Bully for Brontosaurus

What science took away, science has returned to us: Long live the thunder lizard known by children of every age as Brontosaurus.

The dinosaur crashed onto the scene when paleontology was still a young and undisciplined field. In 1883, *Brontosaurus excelsus* — the first long-necked, whip-tailed sauropod to be reconstructed from a fossilized partial skeleton — captured the public's imagination. But that specimen was found at the peak of the heated "Bone Wars," when scientific rigor often took a back seat to finding and naming the most fossils the fastest.

As early as 1903, paleontologists began questioning the validity of Brontosaurus as a species. Skeptics claimed the animal was merely an adult Apatosaurus, another sauropod. Brontosaurus slipped quietly off its pedestal, disgraced in the eyes of science and just a few years later eclipsed in public interest by a new celebrity dinosaur: the agile T. rex.

It seems fitting that, in the same year the New Horizons spacecraft rekindled our appreciation for the demoted dwarf planet Pluto, a young paleontologist would champion a new interpretation of the fossil record that restored the good name of Brontosaurus.

Swiss paleontologist Emanuel Tschopp says redeeming Brontosaurus was not his agenda when he undertook an analysis of the entire diplodocid family, which includes Apatosaurus and fossils once described as Brontosaurus.

"My goal was to identify some diplodocids in a museum in Switzerland, near where I grew up. It was difficult to do so without analyzing the entire group because many of the species were proposed in the late 1800s, based on very fragmentary material," Tschopp says.

Tschopp rebuilt the diplodocid family tree from the ground up by documenting 477 traits in the bones of every specimen available, and then using two different statistical methods to examine the differences among specimens.

"We analyzed much more data with many more diplodocid specimens than ever before, and we took a statistical approach to do it in a reproducible way. It allowed us to quantify *how* different such species are from each other and to establish new, clearer boundaries between them," Tschopp says.

As he reconstructed the branch of the diplodocid tree that included Apatosaurus and erstwhile Brontosaurus fossils, Tschopp saw numerous differences between the two emerge in features on the animals' necks, shoulder blades, ankles and tailbones.

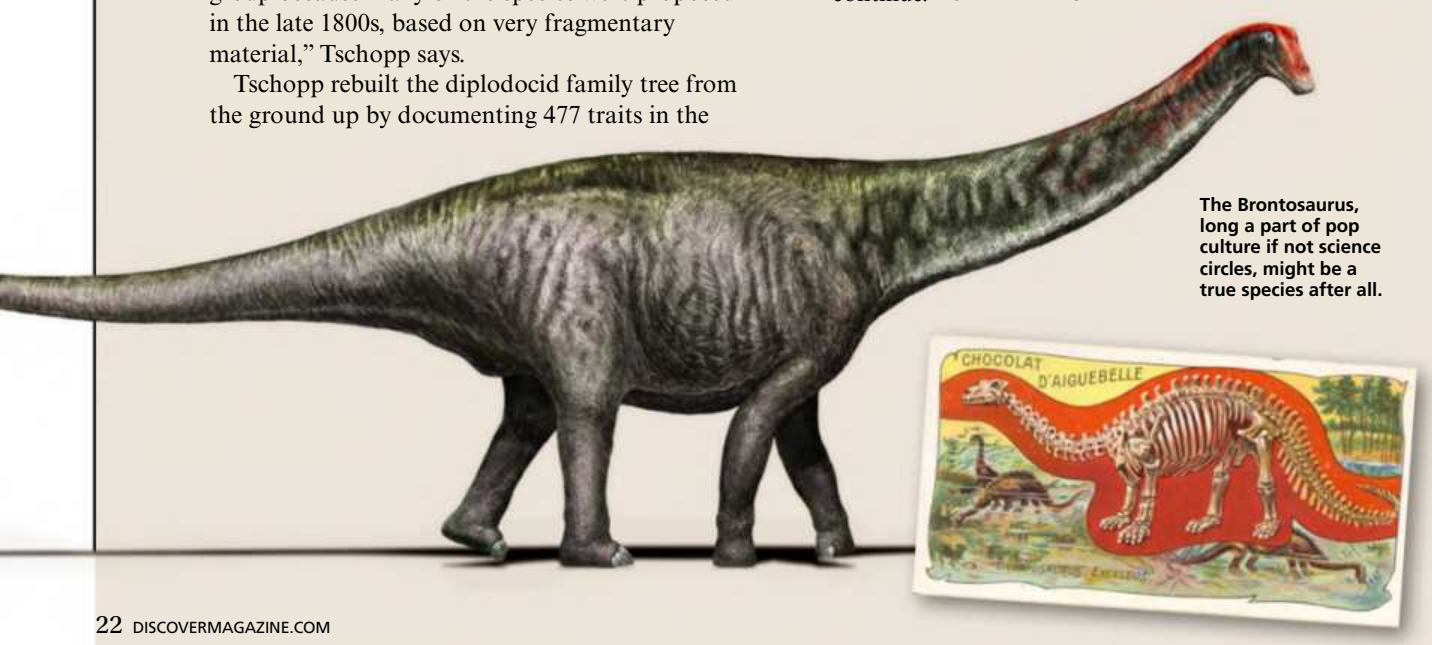
When all 298 pages of Tschopp's analysis were published in April in the online journal *PeerJ*, the dormant Brontosaurus Nation came alive, flooding the Internet with celebration. Brontosaurus was back.

But the story is not over.

Tschopp is now checking the statistical method's accuracy by applying it to living lizards, with the intent of comparing results with DNA analysis. His current research might detect flaws in his *PeerJ* study, throwing the legitimacy of Brontosaurus into question again.

"What we have for Brontosaurus now is a proposition based on good data. But I can't promise anything — that's how science works," Tschopp says. "Because it is so well known, Brontosaurus is a good example to show people that science is always a discussion. We've started a discussion, and we will see what comes next."

For now, Brontosaurus Nation, let the celebrations continue. — GEMMA TARLACH



The Brontosaurus, long a part of pop culture if not science circles, might be a true species after all.

LEFT: DAVIDE BONADONNA, MILAN, ITALY; RIGHT: PUBLIC DOMAIN

13

One Step Closer to Universal Flu Vaccine

Getting an annual flu vaccine is a drag. It takes time. It might not work. It hurts.

Public health experts have long fantasized about giving people one jab that would safely last a lifetime and protect against *all* kinds of flu. That dream is still a long way off, but the prospect of giving people one vaccine that could provide wide protection for at least a few years is getting more realistic.

In a pair of papers in *Science* and *Nature Medicine* in August, two teams of scientists demonstrated a new approach for making a universal flu vaccine.

Figuring out the molecular structure of the flu virus, which researchers detailed in two key papers in 2009, enabled scientists to realize they had been targeting only the head of the virus, which varies by strain. Both new studies took aim at the stem — the stick of the lollipop, as one researcher described it — which doesn't change much with evolution and may make a better target for a universal vaccine.

"Our understanding of protein structure, the virus and the virus life cycle is allowing us to do things that we didn't think was possible even a few years ago," says Gary Nabel, chief scientific officer at drugmaker Sanofi and an author on the *Nature Medicine* paper.

In the end, a vaccine will probably need to take multiple approaches at once, like combination therapy against cancer, says Jeffery Taubenberger of the National Institute of Allergy and Infectious Diseases. He wrote a July *mBio* paper showing the effectiveness of a vaccine made from a cocktail of engineered viruses.

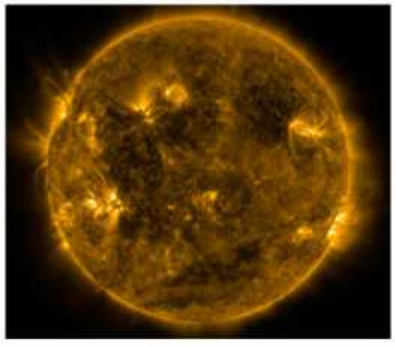
Either approach will take at least another five years of testing before it would be ready to fight seasonal flu, Nabel says. — KAREN WEINTRAUB

FROM TOP: SARAH2/SHUTTERSTOCK; COURTESY OF NASA/SDO AND THE AIA, EVE AND HMI SCIENCE TEAMS; NASA/GODDARD SPACE FLIGHT CENTER

14

Hot Answer to a Solar Mystery

The sun's surface is hot, sure — almost 10,000 degrees Fahrenheit — but the solar atmosphere, or corona, is somehow 4 million degrees. What gives? In April, scientists announced the main reason: small bursts of magnetic energy called nanoflares, which temporarily heat pockets of gas to 20 million degrees.



The sun's atmosphere is even hotter than its surface, possibly due to "nanoflares" confirmed by astronomers this year.

"The sun's surface is much like a pot of hot oil on the stove," says NASA solar scientist James Klimchuk. "Hot oil rises, spreads out horizontally, cools and falls back down to the bottom of the pot, only to rise again." That constant movement can twist and tangle the magnetic fields that thread through the sun and extend into the corona. Eventually, like a rubber band, they reach a point where they snap. Scientists had theorized this would cause a nanoflare.

The tiny bursts, each releasing just one-billionth the energy of a normal flare, proved elusive. But in December 2013, during its 15-minute rocket flight, the Extreme Ultraviolet Normal Incidence Spectrograph spied solar material measuring 20 million degrees, matching nanoflare predictions.

"[These observations] confirm that nanoflares exist and heat at least some of the corona," says Klimchuk. Next up is confirming nanoflares' magnetic births and determining how often they occur. — LIZ KRUESI

Principal investigator Doug Rabin helps calibrate the Extreme Ultraviolet Normal Incidence Spectrograph using colored lights before its latest trip to study the sun.

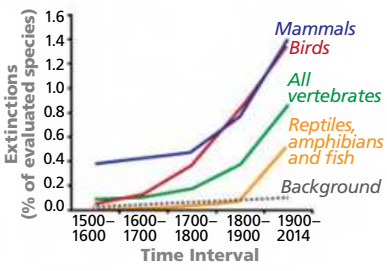
15

Welcome to the Sixth Mass Extinction

Scientists have warned for years that we're heading toward a mass extinction. A June study offered the most damning evidence yet that the sixth great extinction is underway — and that it's driven by us.

Even using more conservative estimates, lead author Geraldo Ceballos of the National Autonomous University of Mexico concluded that species are vanishing up to 100 times faster than they would without human impacts. We are "precipitating a global spasm of biodiversity loss," he wrote in the *Science Advances* study.

Climate change is an increasingly significant driver of that loss,



In the past 500 years, many vertebrate species have perished, primarily due to hunting and loss of habitat. This graph, from a *Science Advances* study, shows the increasing percentage of animals lost over time, compared with the losses that would have occurred naturally (dotted line).

according to a separate analysis published in *Science* in May. University of Connecticut ecologist Mark Urban, who reviewed 131 studies predicting the effects of warming on plants and animals, found that extinction risk accelerates with every degree of temperature rise, as habitats become uninhabitable. If greenhouse gas emissions continue unabated, he says, by 2099, 1 in 6 species will face the prospect of extinction.

Living in a world with fewer species creates a human crisis as well as an ecological one, researchers warn. Biodiversity is essential for human health, economies, food production and cultures, notes Paul Ehrlich, co-author of the *Science Advances* study. "We're sawing off the limb that we are sitting on."

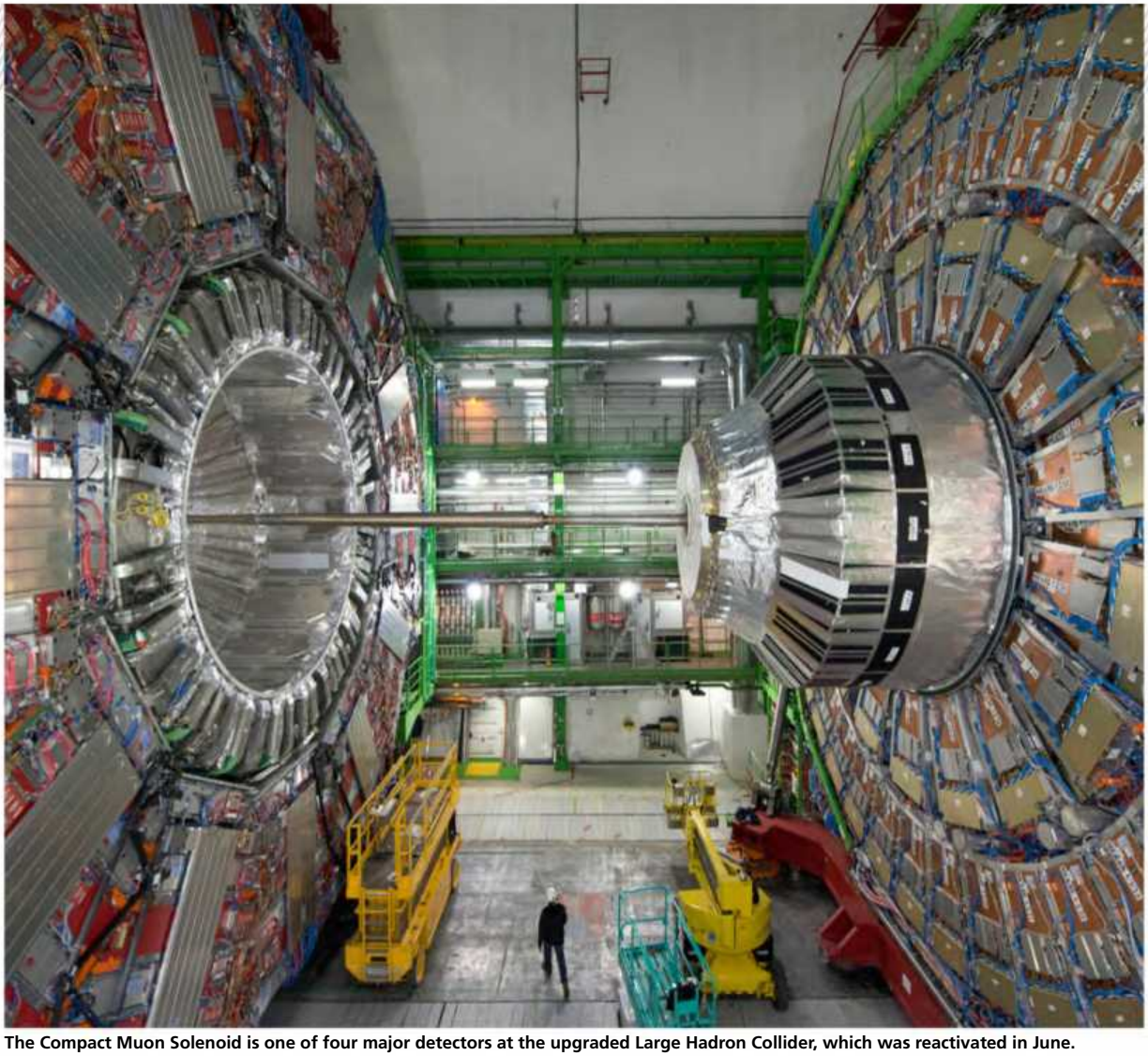
—JANE BRAXTON LITTLE

Sudan, the last male northern white rhino, with a guard at Kenya's Ol Pejeta Conservancy.

Rhino Species Down to a Single Male

Aging and solitary, a rhino named Sudan became a minor celebrity in 2015 for a sobering reason: He is the last remaining male northern white rhinoceros. Since he's too old to reproduce, and his female counterparts are unable to give birth, the survival of his species hinges on human intervention: fertilizing eggs with frozen sperm and implanting the embryo in a young southern white rhino. But the odds of success are low, and Sudan likely won't live to see the outcome. —ALYSSA FAVREAU

TOP: GERALDO CEBALLOS ET AL./SCIENCE ADVANCES/JUNE 19, 2015/10.1126/SCIADV.1400253. BOTTOM: JAN STEŠKAL/OL PEJETA CONSERVANCY



The Compact Muon Solenoid is one of four major detectors at the upgraded Large Hadron Collider, which was reactivated in June.

LHC Back Online, With an Extra Shot

After a two-year shutdown for upgrades and maintenance, the Large Hadron Collider (LHC) — already the world's largest and most powerful particle accelerator — is back online and more powerful than ever. The LHC's particles, which whiz around a 17-mile loop at almost light speed, will now boast nearly twice the collision energy. While the 2012 discovery of the Higgs boson particle was a landmark event, it was basically expected. Physicists hope that with bigger energies come bigger findings: brand-new particles, evidence for theories beyond the Standard Model (the current paradigm) or even the discovery of dark matter's identity. Hold on to your protons. —ANDY BERGER

Technicians at the Large Hadron Collider conduct radiography tests of the connection between an LHC magnet and its diode in March.

TOP: RICHARD JUILLART/AFP/GETTY IMAGES. BOTTOM: MAXIMILIEN BRICE/CERN

17

Touch the Light Fantastic

At a Los Angeles tech show in August, Japanese researchers vaporized visitors' fingertips with high-energy lasers. They were not demonstrating a new form of torture. On the contrary, says principal investigator Yoichi Ochiai, their laser plasma display is the future of entertainment.

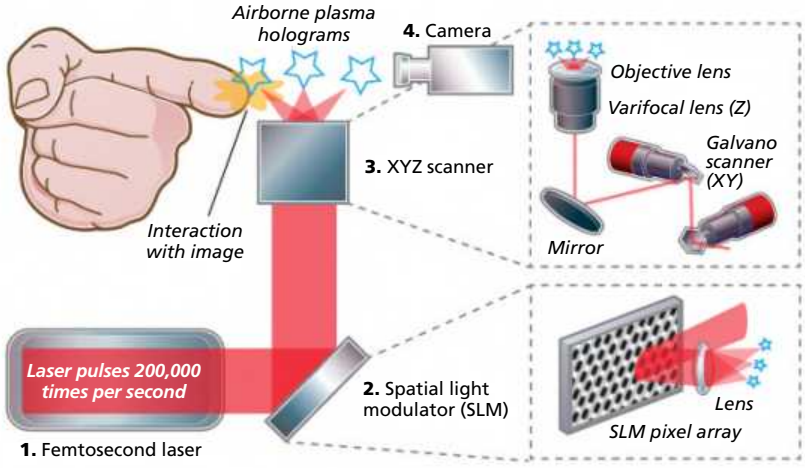
Ochiai has created the first airborne hologram that can be physically felt and manipulated. He's done so by precisely focusing infrared laser light to selectively ionize, or steal the electrons from, air molecules at the beam's focal point, generating a flash of bluish-white plasma. Two-hundred-thousand flashes per second are sufficient to generate a three-dimensional moving image.

Ordinarily, plasma is dangerously hot; Ochiai's tests with nanosecond blasts quickly incinerated bits of leather. But by shortening the bursts from nanoseconds to femtoseconds — quadrillionths of a second — Ochiai's team can make the plasma safe for fingers. Although the ultrashort bursts do ionize the skin's surface, turning it into plasma, it's not long enough to cause damage. Instead, the ionization makes shock waves across the finger's surface, resulting in a tingling sensation. Ochiai says it feels like touching sandpaper.

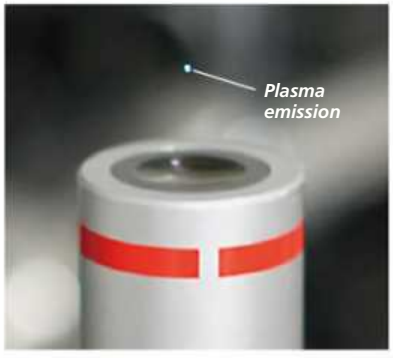
Contact with flesh also causes the plasma to brighten, an effect Ochiai plans to exploit for interactive holograms, noting that the brightening can provide a visual cue for video tracking.

And he intends to go big. Ochiai foresees fully immersive holographic experiences in concert halls and stadiums — as well as aerial 3-D markers for roads and runways — all within decades. "I'm a 28-year-old assistant professor," he remarks. "I think I can make it before my retirement."

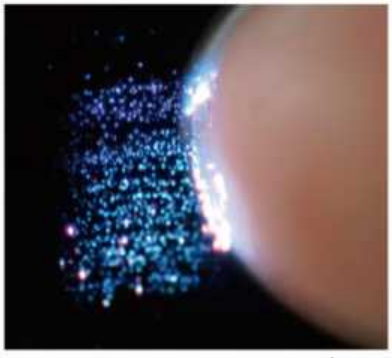
— JONATHON KEATS



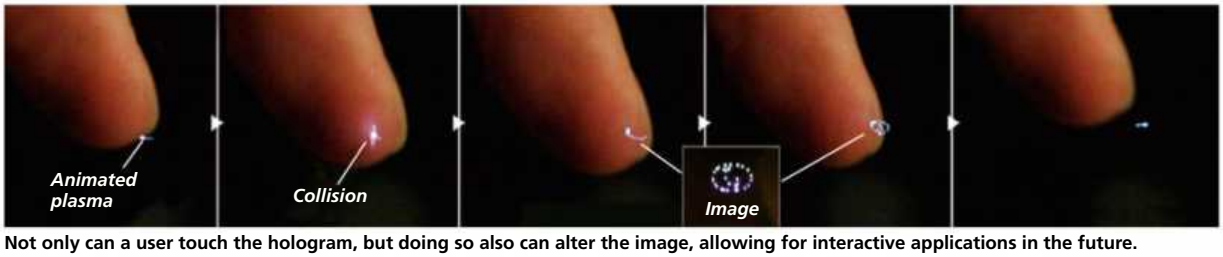
How it works: 1. A femtosecond laser system sends out ultrashort bursts of laser light. **2.** A spatial light modulator, which adjusts laser intensity using an array of computer-controlled pixels, generates a holographic image. **3.** Mirrors focus the beam into position, arranging each individual voxel (the term for 3-D pixels) at specific lateral (X,Y) and axial (Z) points. The focused beam excites the air, ionizing electrons and creating points of bluish-white light. **4.** A camera captures user interaction.



Japanese researchers created a device that can project 3-D holograms using air itself as a medium.



The 3-D holograms, created by superfast laser bursts, are safe to touch, causing a buzzing or tingling feeling.



Not only can a user touch the hologram, but doing so also can alter the image, allowing for interactive applications in the future.

TOP: JAY SMITH AFTER YOICHI OCHIAI ET AL./UNIVERSITY OF TSUKUBA/UTSUNOMIYA UNIVERSITY/NAGOYA INSTITUTE OF TECHNOLOGY/THE UNIVERSITY OF TOKYO/SONY CSL. OTHER IMAGES: YOICHI OCHIAI/UNIVERSITY OF TSUKUBA

The lithium-ion battery dubbed the Tesla Powerwall (upper left) provides enough electricity to run a typical household for a few hours.

Tesla Charges Into Renewable Energy Storage

Tesla's silent electric cars have made a lot of noise in the auto industry by combining cutting-edge green technology with fashionable good looks. Now Elon Musk, the serial entrepreneur and CEO of Tesla, aims to shake things up again, this time targeting renewable energy storage for homes and businesses.

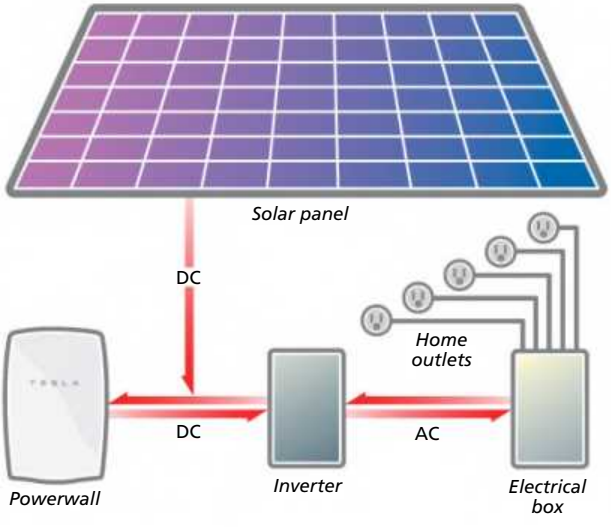
The Tesla Powerwall is a wall-mounted lithium-ion battery that measures about 4 feet tall by 3 feet wide and resembles a sleek circuit breaker box. It comes in two storage capacities — 7 or 10 kilowatt-hours — that provide enough electricity to run a typical household for a few hours. Starting at $3,000, the Powerwall is meant to capture energy from renewable but intermittent sources, like solar, stockpiling it for later use. By transforming solar energy from a sporadic source to a dependable one, Musk hopes his batteries can help wean us off fossil fuels.

The Powerwall does have its detractors, with one commentary piece in *Forbes* calling it "just another toy for rich green people." And when considering cost alone, an analysis showed the Powerwall isn't competitive with a gas generator.

But Tesla, which announced the new battery in April, has already received pre-orders worth over $800 million for the Powerwall and Powerpack, the 100-kwh version capable of stacking together to power utility-scale installations.

Before electric cars started gaining traction five years ago, lithium-ion batteries were good primarily for powering laptops and cell phones for a few hours. By plugging them into cars and squeezing nearly 300 miles out of a single charge, Tesla helped drive battery technology, and a reluctant auto industry, forward. Now Musk is betting on a solar energy future in which we can keep our lights on long after our rooftops have gone dark.

— ANDY BERGER



The Powerwall battery is charged with electricity generated by solar panels or from the utility grid. An inverter converts direct current (DC) electricity into the alternating current (AC) used by the lights, appliances and devices in a home.

BOTH IMAGES: TESLA MOTORS

19

Brain Scans May Lead to Better Diagnoses

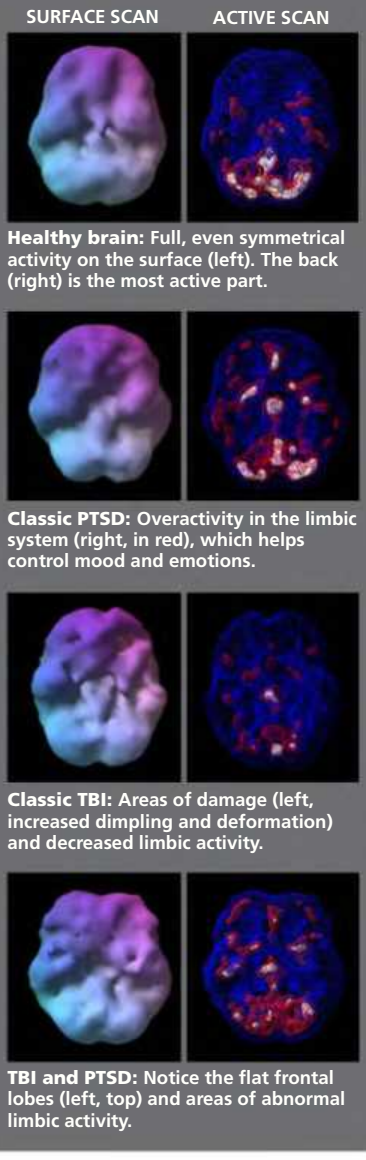
Over a million soldiers have served in the wars in Iraq and Afghanistan. Of the men and women who have returned from combat, more than 100,000 have been diagnosed with post-traumatic stress disorder (PTSD). Over 300,000 more have been told they have a traumatic brain injury (TBI). In many cases, symptoms are the same: insomnia, anxiety, irritability, poor concentration and limited impulse control.

The treatments for these two conditions are very different. The problem is, there hasn't been a consistently accurate diagnostic test to distinguish between PTSD and TBI. That changed earlier this year when two studies, one of which involved 20,746 patients, found that a type of medical imaging called single photon emission computed tomography (SPECT) showed clear differences in the brains of people with TBI or PTSD. Largely through analyzing how well blood flows (or doesn't) through various parts of the brain, SPECT scans show with 80 to 100 percent accuracy whether someone has TBI, PTSD or both.

Understanding which is which is huge. Physical damage from TBIs, for example, can depress brain activity. If a doctor mistakes it for PTSD and prescribes sedatives that are often helpful for that condition, those drugs can further dampen cerebral function and worsen symptoms.

"If you go for help and the help is ineffective, it's not a neutral experience," says Daniel Amen, founder of Amen Clinics and lead author of the larger study, which was published in July. "It wastes time and money, it's demoralizing, and it can hurt people." —CHRISTIAN MILLMAN

TBI and PTSD Scan Comparison Chart



Healthy brain: Full, even symmetrical activity on the surface (left). The back (right) is the most active part.

Classic PTSD: Overactivity in the limbic system (right, in red), which helps control mood and emotions.

Classic TBI: Areas of damage (left, increased dimpling and deformation) and decreased limbic activity.

TBI and PTSD: Notice the flat frontal lobes (left, top) and areas of abnormal limbic activity.

DANIEL AMEN, M.D./AMEN CLINICS INC.

Chilesaurus: The One That Went Vegan

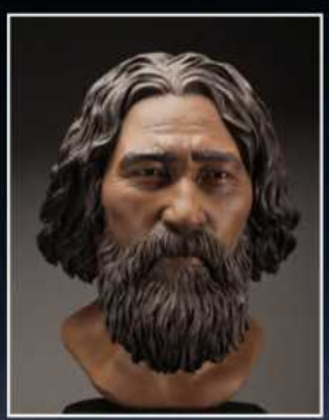
20

Discovering one of South America's most intriguing dinosaurs was child's play: Diego Suarez was just 7 when he found the first fossils of the 145-million-year-old herbivore that would bear his name, *Chilesaurus diegosuarezi*. The hard work began when paleontologists tried to fit it into the dinosaur family tree. *Chilesaurus*, which grew to about 10 feet long, has a previously unseen mix of primitive and advanced skeletal features. After analyzing fossils from more than a dozen specimens, researchers reported in April in *Nature* that the herbivore was actually a kinder, gentler cousin of such bitey carnivores as *T. rex* and *Velociraptor*. *Chilesaurus* is a rare example of a species from the generally predatory theropod group that evolved into a plant-eater.

—GEMMA TARLACH

CHAD EDWARDS

21



A facial reconstruction (left) of Kennewick Man's skull shows what he may have looked like nearly 9,000 years ago. A new DNA analysis of a bone fragment found that the skeleton shares ancestry with modern Native Americans, likely settling a lengthy debate over rights to the bones.

CHIP CLARK/SMITHSONIAN INSTITUTION. INSET: BRITTNEY TATCHELL/SMITHSONIAN INSTITUTION

Analysis Establishes Kennewick Man's Ancestry

A new DNA analysis of a bone fragment from an ancient skeleton may have settled an almost 20-year debate between Native Americans and scientists over rights to the bones.

The analysis shows that Kennewick Man — a nearly 9,000-year-old skeleton found in 1996 in Washington state — shares ancestry with modern Native Americans. The analysis also allowed the researchers to link the skeleton to a specific group of Native Americans.

Evolutionary geneticist Eske Willerslev of the University of Copenhagen, who has sequenced other ancient DNA samples, led the team that extracted DNA from a tiny fragment of hand bone and used it to sequence the skeleton's genome. The analysis, published in June, showed that Kennewick Man is related to modern Native Americans and shares ancestry with members of the Confederated Tribes of the Colville Reservation, who were among the groups claiming the bones as their own since the discovery. They contended that the bones should be reburied instead of remaining with scientists for research. In 2004 they lost a federal court case, and scientists were allowed to continue studying the skeleton.

—ZACH ZORICH

ALEXANDRA THOMPSON/ISTOCK

Team Identifies Genetic Markers for Depression

The search for a genetic link to depression, which affects 350 million people worldwide, has come up empty for years. While some people become depressed after a mild stressful event, others remain resilient to catastrophe. A British researcher and his team found two areas in the genome that appear to be key to depression.

To make sure he recruited only patients with major depression, Jonathan Flint, a psychiatrist from the University of Oxford who led the study, says he examined older generations of Han Chinese women. As a result, his patients did not have many of the complicating factors of depression. "None of them drink alcohol, none of them smoke, and other drug abuse is rare," he says.

Flint's team collected DNA samples from more than 5,000 women with major depression and an equal number of controls. Gene sequencing revealed two regions associated with major depressive disorder on one of the 23 pairs of chromosomes. One was key because it lies near the gene *SIRT1*, which is important for the energy-producing parts of cells called mitochondria.

The finding, reported in July, shifts the focus of depression's source from neuron function to metabolism, which could lead to more effective diagnosis and drug treatments, Flint says.

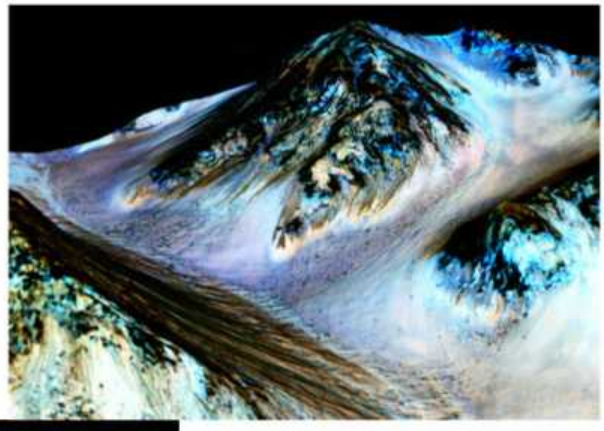
—HEATHER STRINGER

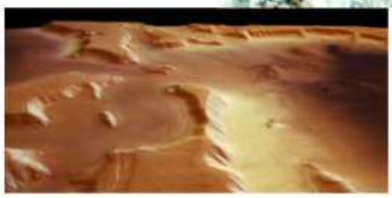
23

Mars: Wetter Than Ever

Mars was a major disappointment, at first. Although the planet had been long seen as the home of elaborate alien civilizations imagined by the likes of H.G. Wells, NASA's 1965 Mariner 4 probe glimpsed a dry and cratered place unlikely to support life. Each subsequent mission to the Red Planet, however, has found a slightly wetter world. And we now know that saltwater ice lurks just below the surface, occasionally breaking through as liquid water.

In September, NASA announced evidence that when the warm season strikes, the briny substance briefly bursts above Mars' sandy slopes, flowing as liquid for hundreds of feet in narrow streaks. The agency's Mars Reconnaissance Orbiter picked out the chemical fingerprints of hydrated minerals there, the first direct evidence that liquid water can still exist on the surface under certain circumstances, though years of evidence had implied as much.





A false color image (top) shows liquid as dark, narrow streaks (bottom left); glaciers also lurk beneath the planet's dust (above).

In recent years, MRO has also revealed vast glacial deposits. These belts wrap around the planet's central latitudes in the northern and southern hemispheres, hidden beneath a thick layer of dust that protects them from the sun. In 2015, researchers from the Niels Bohr Institute in Copenhagen, Denmark, modeled these glaciers using MRO radar measurements and showed that, if melted, their water could cover the entire Red Planet in a sea 3 feet deep. Aside from stoking hopes that Mars might nurture microbial communities, the deposits could also provide crucial water supplies for any future human visits.

And MRO wasn't alone in its watery finds in 2015. NASA's eyes on the ground — the Curiosity rover — found clues that liquid brine could also lurk just beneath its wheels at night. The craft's weather instrument recorded temperature and humidity levels that would likely result in saltwater formation, albeit in amounts and temperatures unfavorable to life. —ERIC BETZ

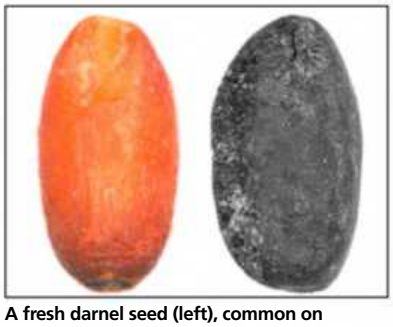
24

The First Farmers

The Agricultural Revolution of 12,000 years ago was apparently not so revolutionary.

Researchers traditionally draw the divide between Paleolithic hunter-gatherers and Neolithic farmers about 12 millennia ago, with the onset of agriculture in the Middle East. But a study published in July in the online journal *PLOS One* indicates that at least in one corner of modern-day Israel, humans were farming 23,000 years ago.

Since 1989, archaeobotanist Ehud Weiss of Israel's Bar-Ilan University and his team have collected some 150,000 specimens of plant remains from the settlement known as Ohalo II. Located on what was the shore of the Sea of Galilee 23,000 years ago, when water levels were significantly lower, the site was eventually destroyed by fire.



A fresh darnel seed (left), common on cultivated land, is similar to a charred archaeological seed (right) found at Ohalo II.

The charring helped preserve plant remains at the site, which was then buried by sediment and inundated as the sea expanded. This preserved it for millennia, despite subsequent intense agricultural activity in the area. As the waters receded due to drought, the site was exposed.

The researchers previously found evidence that Ohalo II's residents were grinding wheat, barley and oats, and also gathering other ancient cereals, but believed these activities involved harvesting wild plants. In the new findings, the team identified large numbers of early weed species at the site that would thrive only in land prepared for agriculture.

"The Ohalo II people were clearing land, sowing wheat and barley and harvesting them," says Weiss. —GEMMA TARLACH

FROM TOP: NASA/JPL-CALTECH/UNIVERSITY OF ARIZONA; ESA/DLR/FU BERLIN; COURTESY OF EHUD WEISS/THE MARTIN (SZUSZ) DEPARTMENT OF LAND OF ISRAEL STUDIES AND ARCHAEOLOGY/BAR-ILAN UNIVERSITY

Antarctica Under Siege

25

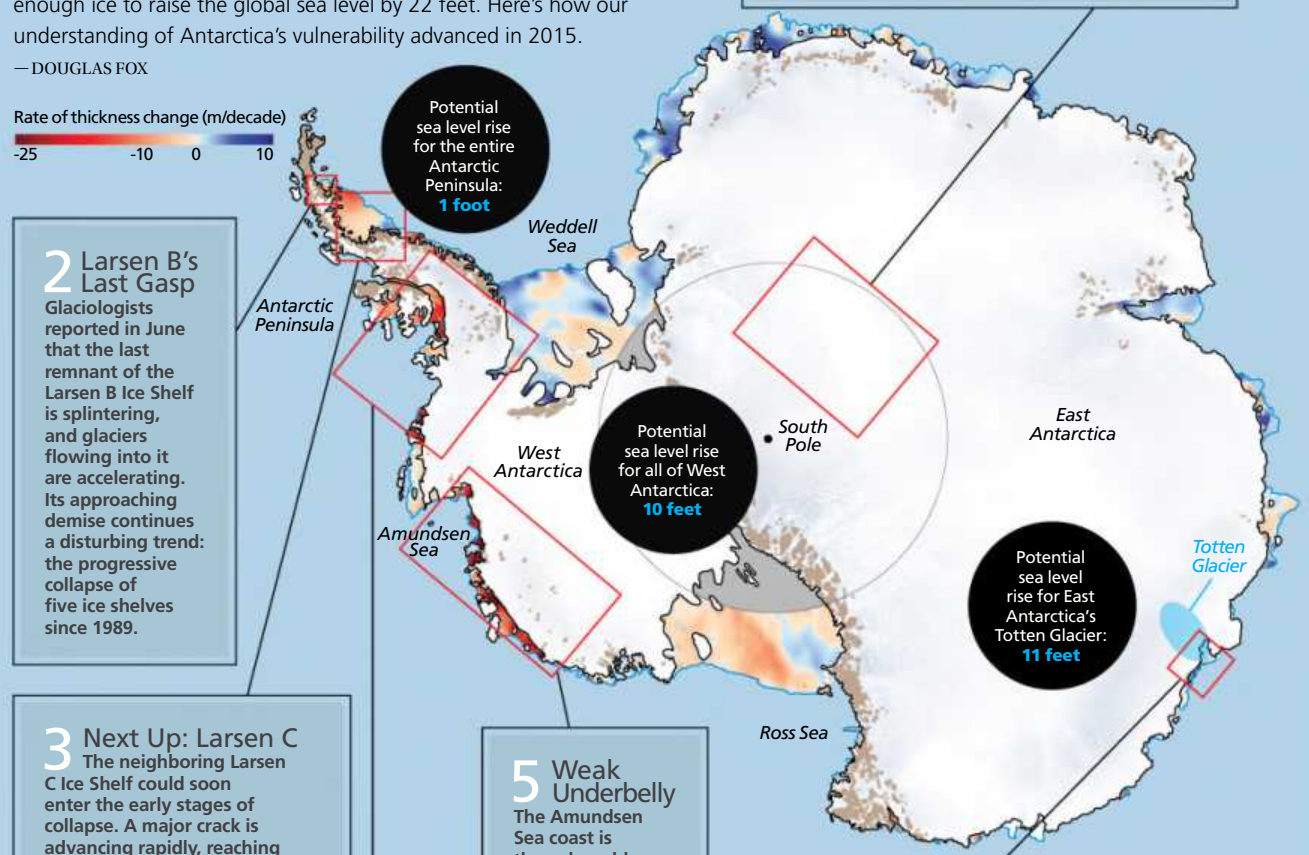
Antarctica is losing more ice than ever, scientists reported in 2015. Its ice shelves — the thick, floating slabs that encircle the continent — are taking the biggest hit. The shelves slow and stabilize the glaciers behind them, but they are succumbing to a hidden force: Deep, warming ocean currents are melting the ice from beneath.

The collapse of several small ice shelves has caused glaciers to accelerate two- to ninefold and spill more ice into the ocean, raising the sea level. A study published in April shows that more ice shelves are coming into play: From 1994 to 2012, the rate of ice shelf shrinkage increased twelvefold. Parts of the ice sheet considered at risk hold enough ice to raise the global sea level by 22 feet. Here's how our understanding of Antarctica's vulnerability advanced in 2015.

— DOUGLAS FOX

1 More Snow (But Less Ice)

Climatologists speculated in the 1990s that Antarctica might actually slow the rate of global sea level rise. They expected that rising temperatures would produce more water vapor, leading to more snowfall and more ice. Researchers reported in March that over the past 20,000 years, warmer temperatures have indeed correlated with higher snowfall: For each Fahrenheit degree of warming, snowfall increased by about 2.7 percent. But that hasn't translated into a reversal of Antarctica's ice loss.



2 Larsen B's Last Gasp

Glaciologists reported in June that the last remnant of the Larsen B Ice Shelf is splintering, and glaciers flowing into it are accelerating. Its approaching demise continues a disturbing trend: the progressive collapse of five ice shelves since 1989.

3 Next Up: Larsen C

The neighboring Larsen C Ice Shelf could soon enter the early stages of collapse. A major crack is advancing rapidly, reaching an unprecedented 60 miles long in early 2015.

4 Southern Peninsula Starts to Sweat

While the glaciers in this region seemed stable, it turns out warming ocean currents have been melting the underside of the ice. Results published in May show this region crossed an invisible threshold in 2009, with a dozen major glaciers simultaneously starting to thin, sweating off 60 billion tons of ice per year.

5 Weak Underbelly

The Amundsen Sea coast is the vulnerable underbelly of West Antarctica. Its glaciers slide on beds that lie nearly a mile below sea level, exposing them to ocean currents. New data show ice shelves are collectively losing 100 billion tons of ice per year, and glaciers have accelerated by up to 70 percent.

6 Hidden Hazards in the East

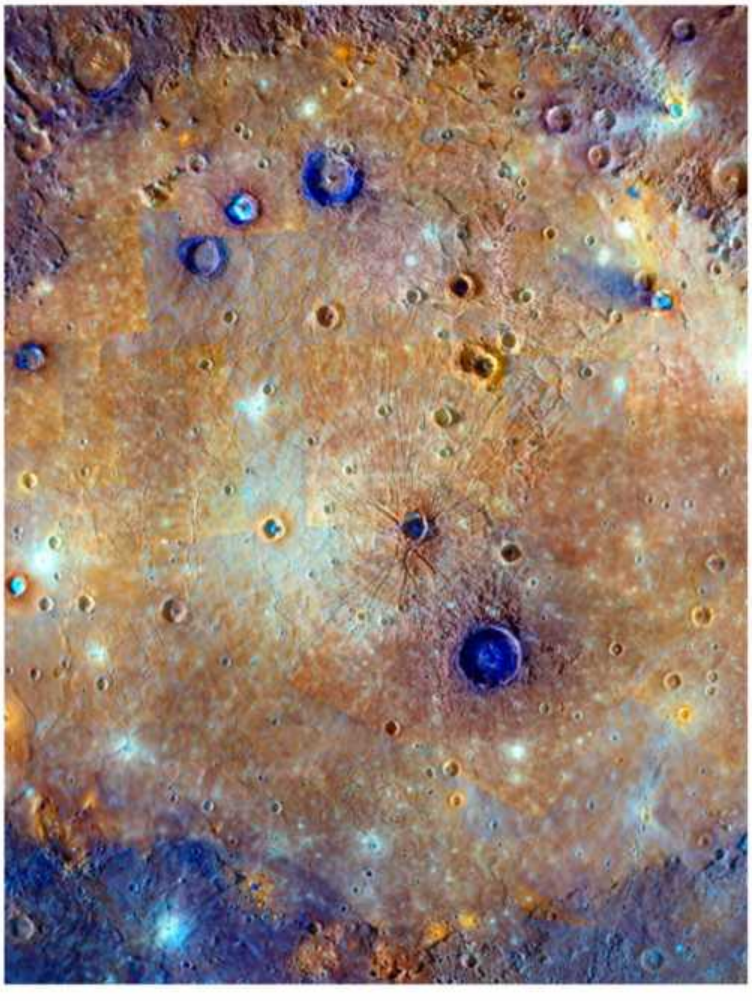
East Antarctica, situated on high ground that protects it from warming ocean currents, was considered stable. But not exactly, according to surveys with ice-penetrating radar. A March study shows that one large swath of the ice sheet sits on beds as deep as 8,000 feet below sea level and is connected to warming ocean currents. Totten Glacier, one of East Antarctica's largest ocean outlets, is already thinning — an ominous sign, since this single glacier drains enough ice to raise the sea level more than all of West Antarctica's ice loss would.

KELLIE JAEGER/DISCOVER

26

A Final Message From Mercury

Mercury was the "dead" planet when NASA's MESSENGER mission launched in 2004. But the spacecraft's 2011 orbital arrival, and more than 250,000 subsequent images, documented an active planet. Running on fumes this year, MESSENGER (short for Mercury Surface, Space Environment, Geochemistry and Ranging) saved the best for last, swooping just miles above the virtually atmosphereless planet. It gathered fresh evidence for frozen water in crater corners, strange rock features called hollows and the evolution of a magnetic field almost 4 billion years old. The craft finally smacked into Mercury at 8,800 mph on April 30. This view of 1,000-mile-wide Caloris basin — among the largest known asteroid impacts in the solar system — shows how lava (orange) filled the blast site before new craters excavated the original basin (purple). —ERIC BETZ



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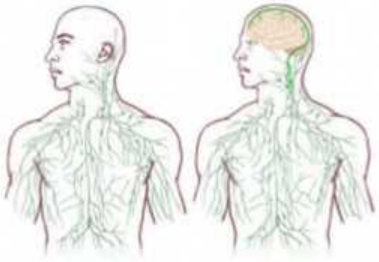
Missed Immune Connection



It shouldn't have been there, but there was no denying that it was there: a channel guiding immune cells directly into the brain. The serendipitous discovery by a University of Virginia team may eventually help explain many neurological diseases.

Previously, researchers assumed immune cells took an indirect route around the brain, flowing freely through its surrounding fluid. That's because lymphatic vessels, which transport immune cells throughout the body, stopped at the upper neck. So neuroimmunologist Jonathan Kipnis and his team weren't looking for lymphatic vessels actually entering the brain. "You don't look for something that doesn't exist," Kipnis says.

But when Antoine Louveau, a researcher in Kipnis' lab, developed a dissection technique that wholly preserves the fragile membranes covering the mouse brain, it revealed something never seen before: Immune cells in the membranes were clearly organized, as if traveling within tubes. Staining confirmed there were tubes and that they were indeed lymphatic vessels — the first proof they existed in the brain.

The findings, published in *Nature* in July, could unearth the secrets of neurological diseases and disorders, like multiple sclerosis and Alzheimer's, that may involve the immune system. "It is very possible that the answer to this question is within the lymphatic vessels," Kipnis says. —TEAL BURRELL

TOP: ANITA IMPAGLIAZZO. BOTTOM: NASA/JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY/CARNEGIE INSTITUTION OF WASHINGTON

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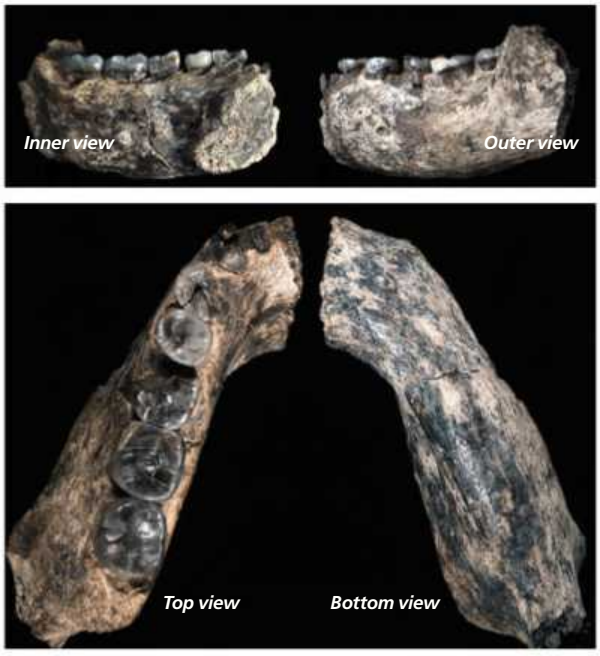
28

The First of Our Kind

A piece of fossilized jaw discovered at Ledi-Geraru, Ethiopia, pushes back the date when the first members of the human genus evolved by 400,000 years. The research, published in March in *Science*, shows that the jaw is about 2.8 million years old. It's one of the few hominin fossils that date to between 2.5 million and 3 million years ago, when a small-brained australopith was evolving into the larger-brained *Homo* genus.

During this period, a changing climate forced our ancestors to move out of the forests and into more open territory. They had to adapt to new foods and new predators, which may have spurred the development of our distinctly larger brains. Animal fossils found near the jaw fragment suggest the individual lived in a savannah environment.

"It confirms this idea that our lineage, *Homo*, is a response to climate change," says Brian Villmoare, a paleoanthropologist at the University of Nevada, Las Vegas. "If the climate had not changed at 3 million years ago, *Australopithecus* could very contentedly still be existing." —ZACH ZORICH



The oldest *Homo* fossil is a piece of jaw that's 2.8 million years old.

29

It's Alive! Well, Sort of

Dr. Frankenstein wishes he were this good: In June, Massachusetts General Hospital researchers announced they'd built the first functioning lab-grown limb. The team amputated a dead rat's forearm and chemically stripped away living cells, leaving behind what's called the extracellular matrix, a kind of scaffolding for everything from blood vessels to nerve networks. The limb then spent two weeks growing muscular and vascular cells in a custom-built bioreactor. Electrical stimulation showed the resulting limb had a grip strength 80 percent that of a newborn rat's. After being transplanted onto a living rat, the limb circulated blood through its new vessels. —LACY SCHLEY

TOP: WILLIAM H. KIMBEL/ARIZONA STATE UNIVERSITY. BOTTOM: BERNHARD JANK, MD, OTT LABORATORY, MASSACHUSETTS GENERAL HOSPITAL CENTER FOR REGENERATIVE MEDICINE

Houseboats ply the shrinking waters of Lake Oroville in Northern California.

West Scorches as Drought Intensifies

A snowboarder attempts a run at the Squaw Valley Resort in California.

California has spent most of the past 15 years in drought, but 2015 was exceptional. The Sierra Nevada normally hits maximum snowpack for the year in early April, but by April 1, alpine meadows usually buried in 5 feet of snow were bare. The snowpack stood at just 5 percent of its average level. A September study of tree-ring records revealed the mountain range had not been this dry in at least 500 years. And yet for all its severity, this drought also has been one of paradoxes.

The amount of rain and snow falling on the northern Sierras, where the drought hit hardest, wasn't actually that low — just 25 percent below average for the first half of 2015. "What makes this drought especially bad is that the last four years have also been extraordinarily hot," says Peter Gleick, president of the Pacific Institute, an Oakland, Calif.-based water think tank. California weathered its hottest year on record in 2015. The excessive heat increased the rate of water loss by evaporation and caused precipitation to shift from snow to rain, leaving a meager snowpack and parched reservoirs.

Some California reservoirs shriveled by two-thirds, forcing the state in April to issue mandatory water restrictions for the first time in its history. Two months later, state officials suspended water allocations to farms, idling 840 square miles of fields.

The current drought is part of a larger pattern of warmth and dryness gripping the West and central Plains. Texas, New Mexico, Oklahoma, Kansas and Nebraska suffered severe drought between 2011 and 2013. Drought struck California and Nevada beginning in 2012, and in 2015 it spread into Oregon and Washington. By midsummer, low stream flows and warm water had killed half the annual sockeye salmon breeding run in the Columbia River. Large wildfires fed by dry vegetation scorched the West Coast.

The drought may ease this winter, with warm Pacific El Niño waters expected to trigger heavy precipitation in parts of the West. But it's likely to be a short reprieve. A study published in February suggests that a mega-drought lasting at least 35 years is 60 to 80 percent likely to occur in the Southwest or central Plains after 2050.

Groundwater across the West has been depleted from overuse, shrinking aquifers that cities and farms typically relied on during dry times. Forty cubic miles of water — enough to fill 64 million Olympic swimming pools — have disappeared from beneath California's Central Valley alone. "We basically no longer have a buffer," says Gleick. —DOUGLAS FOX

FROM TOP: RICH PEDRONCELLI/AP/CORBIS; MAX WHITTAKER/GETTY IMAGES

31

Fiery 2015 May Become 'The New Normal'

Flames swept across more than 9 million acres from Alaska to Texas in 2015, burning through forests, grasslands, tundra — and over half the U.S. Forest Service budget. That much scorched earth was unheard of 30 years ago, and the U.S. isn't alone: Wildfires are gaining ground worldwide, according to a July study.

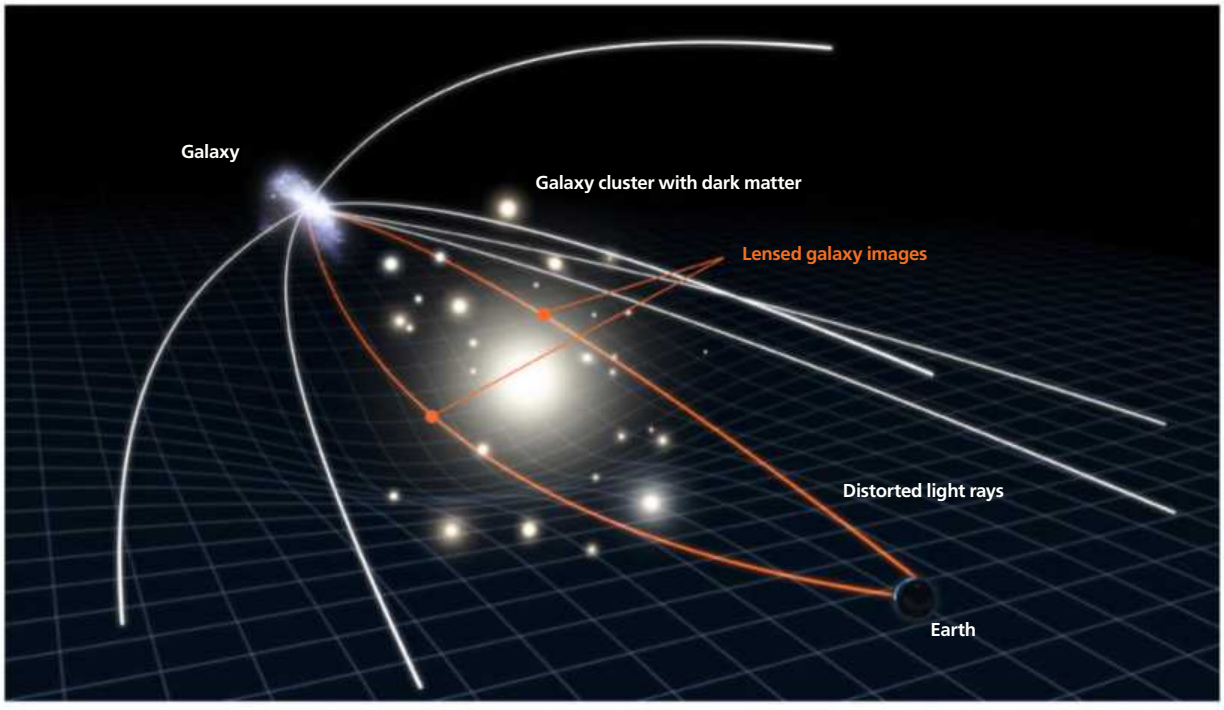
In the U.S., fire seasons are now 78 days longer than in the 1970s, and the burned acreage is projected to double by 2050, according to the Forest Service. Within a decade, suppressing fires will consume two-thirds of the Forest Service's annual budget, with "no end in sight," says agency Chief Tom Tidwell.

Globally, nearly every continent faces longer fire seasons, a trend tied to the changing climate, according to the July study published in *Nature Communications*. Between 1979 and 2013, increases in temperature and wind speeds along with more rain-free days combined to stretch fire seasons worldwide by nearly 20 percent.

"The norm is shifting," says lead author W. Matt Jolly, a Forest Service fire ecologist. "What we're seeing now may be the new normal." — JANE BRAXTON LITTLE

The Lake Fire in California's San Bernardino County scorched more than 30,000 acres in the summer of 2015. By late fall, about 9.3 million acres had burned in the U.S., placing 2015 among the top four worst fire seasons since 1960.

STUART PALLEY



Dark Matter Pushback

Astronomers have long thought dark matter — the famously invisible mystery substance that glues together galaxies and galaxy clusters — interacts with any material only by its gravitational pull. But last April, scientists announced the first evidence that dark matter may also use friction to push against itself.

One of the tricks astronomers use to study dark matter — which, being invisible, can only be studied indirectly — is gravitational lensing. Anything with mass warps the nearby space, so as light passes near that massive object, its path bends, following the warps. Sometimes that can result in a faraway object appearing distorted or even multiple times around a nearer massive object, like a menu viewed through the bottom of a wine glass.

Using the Hubble Space Telescope, astrophysicist Richard Massey at England's Durham University and colleagues identified some 30 magnified and warped images of a distant background spiral galaxy that appeared in the core of a nearby cluster of galaxies. Through gravitational lensing, the spiral galaxy's light essentially photobombed the cluster and, in doing so, illuminated how matter — both light and dark — is distributed within the cluster and around one of its four central galaxies.

An object's gravity can distort the light traveling nearby (top). Astronomers took advantage of this "gravitational lensing" to study the dark matter within galaxy cluster Abell 3827 (above), where a distant blue galaxy's light spirals around four galaxies.

"We noticed that the dark matter seems to have become separated from [at least one of the central galaxy's] stars," says Massey. "That implies that it was acted upon by different forces, and followed a slightly different trajectory. The most plausible option … is the dark matter in at least one of the galaxies is feeling a frictional force from the dark matter in the cluster." That is, dark matter is pushing against itself, a totally unexpected behavior for the ethereal material.

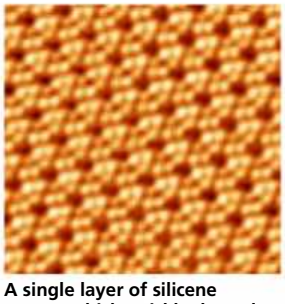
—LIZ KRUESI

TOP: NASA, ESA AND L. CALÇADA. BOTTOM: NASA/ESA/ESO

33

First Silicene Transistor

When it comes to electronics, smaller is usually better. And as devices get more compact and powerful, they need ever-tinier transistors — the internal switches that keep computers computing. Easy to use and abundant, silicon has been the go-to transistor material for decades, but in February, the world saw the first silicene transistor.

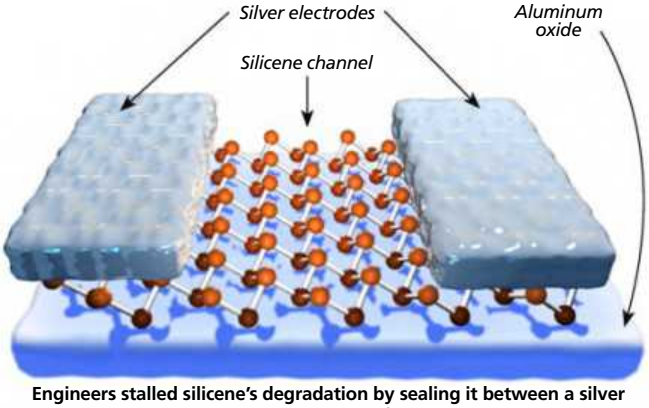


A single layer of silicene atoms, which quickly degrade in air unless protected.

Silicene is a two-dimensional version of silicon just a single layer of atoms thick. It behaves like a superstrong electron superhighway, a quality that may lead to flexible and transparent electronics. Silicene debuted in 2012, but it degrades within seconds when exposed to air. "It needs to be protected at all times," says Deji Akinwande, the University of Texas at Austin engineer who led the work.

So Akinwande's team first grew silicene on a silver base and, to stall degradation, sealed it under an aluminum oxide layer. Finally, they flipped the transistor over and used a custom-developed solution to etch out a silver slice in the middle while preserving the underlying silicene. The result: a silicene channel for electrons to travel from electrode to electrode.

The transistor represents a major advance but has a ways to go — even in a vacuum chamber, it still degraded within a few minutes. —STEPHEN ORNES



Engineers stalled silicene's degradation by sealing it between a silver base and an aluminum oxide layer. They flipped it and etched out some silver to form two electrodes while still preserving the silicene.

34

Psychologists Enact Interrogation Ban

In August, the Council of Representatives of the American Psychological Association (APA) voted 157-1 to ban psychologists from participating in national security interrogations for military or intelligence entities.

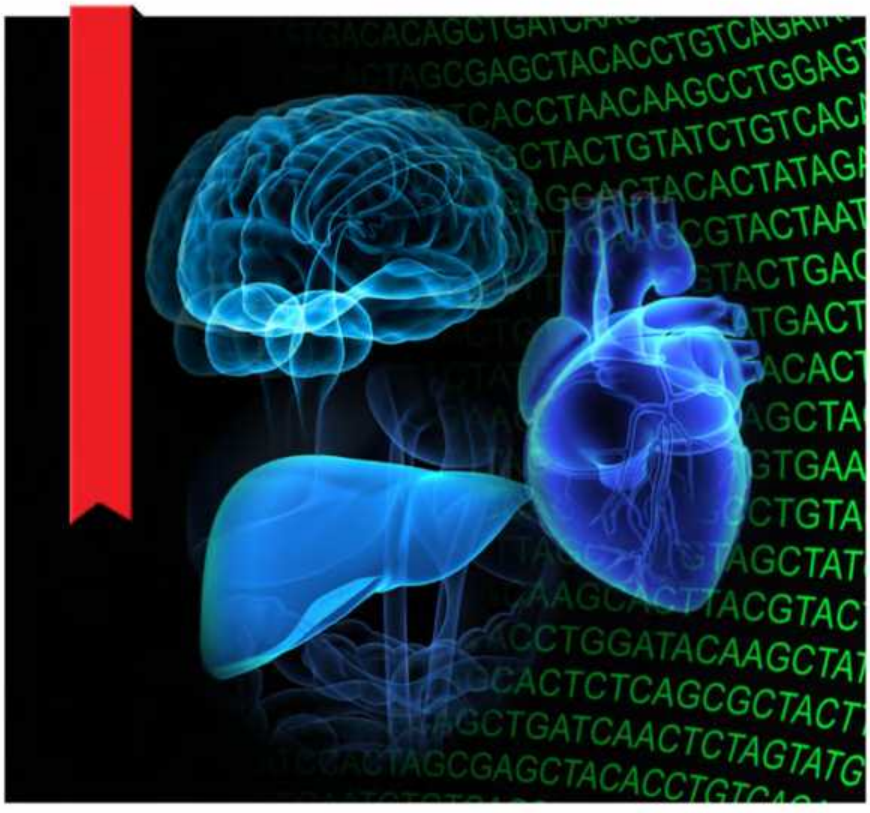
The move comes after years of work by a small group of psychologists who exposed the APA's role in legitimizing the U.S. government's use of torture in the war on terror.

For nearly a decade, the APA denied claims made by the group. But last year — after James Risen of *The New York Times* published *Pay Any Price: Greed, Power and Endless War*, which documented the APA's collusion in torture — the organization commissioned an independent review to examine the accusations.

The analysis confirmed the APA's secret collaboration with the Department of Defense (DOD) and CIA on "enhanced interrogation" programs, including waterboarding, sleep deprivation and other extreme tactics, during George W. Bush's presidency. In late July, the APA apologized for the "extremely troubling and painful" revelations.

The APA's sanctioning of the practices was critical to the Bush administration's claim it was acting within the law, because it allowed the DOD and CIA to argue the tactics were "safe and effective and therefore legal," says Widney Brown, director of programs at Physicians for Human Rights. The ban represents a critical step toward accountability for those who participated in torture, she says. —CHRISTIE ASCHWANDEN

CLOCKWISE FROM TOP LEFT: COURTESY ALESSANDRO MOLLE/LABORATORIO MDM, IMM-CNR, ITALY; COURTESY OF JO WOZNIAK AND DEJI AKINWANDE/UNIVERSITY OF TEXAS-AUSTIN; ALEX WONG/ISTOCK



Team Maps the Human Epigenome

In the 12 years since the Human Genome Project was completed, biologists have linked more than a thousand regions of the genome to disease. "But in most cases, we don't actually know how they function," says Manolis Kellis, a computational biologist at Massachusetts Institute of Technology.

Enter the epigenome. If the human genome is the book of life, the epigenome is the collection of bookmarks and highlighting that tells the cell what passages of the book to read. These marks include chemical tags on DNA that make genes unreadable, as well as chemical tags on proteins that help expose DNA inside the cell nuclei, making genes readable. They're the reason that cells from the liver, heart or brain differ profoundly. The National Institutes of Health Roadmap Epigenomics Consortium, including Kellis, published the most comprehensive map of the human epigenome in February.

Kellis led the data analysis team, which applied machine-learning algorithms to decode the language of the epigenome. The map serves up important clues about how a single fertilized egg can develop into the diversity of tissues in the human body — and how healthy tissue can become diseased. For example, one team in the consortium reported how metastatic cancer cells contain an epigenetic fingerprint that reveals the tissue they came from, which could lead to better-targeted cancer treatments. Another team reported spotting DNA sequences that may trigger autoimmune diseases.

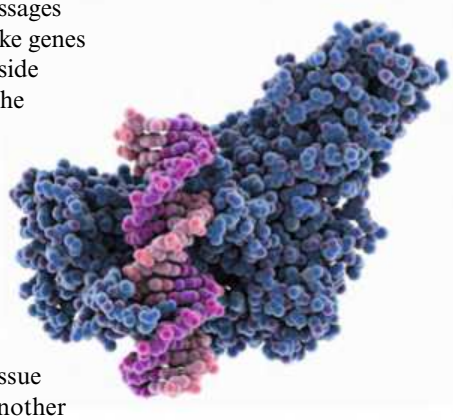
—DAN FERBER

Cracking Mutations' Disease Code

Thousands of mutations are linked to disease, yet only a few cause illness by directly disrupting proteins, the cell's workhorses. Scientists have figured out how several of the other mutations spur disease.

Using thousands of tissue samples from cadavers, researchers on the Genotype-Tissue Expression project (GTEx) isolated and sequenced DNA and a variety of protein-encoding RNAs from each sample. Many disease-linked mutations, it turned out, lie in stretches of DNA that don't encode proteins themselves but instead regulate genes elsewhere in the genome that then go on to disrupt tissue function.

Genomic makeup also can affect to what extent genes are turned on or off in a person's tissues, thereby causing disease, says Kristin Ardlie, a Broad Institute biologist who co-led the analysis published in May. —DF



A model shows chemical tags, which can silence genes, surrounding a DNA strand (pink).

TOP: ILLUSTRATION BY DAN BISHOP/DISCOVER WITH 7ACTIVESTUDIO/ISTOCK, ERAXION/ISTOCK, FREDEX/SHUTTERSTOCK. BOTTOM: LAGUNA DESIGN/SCIENCE SOURCE

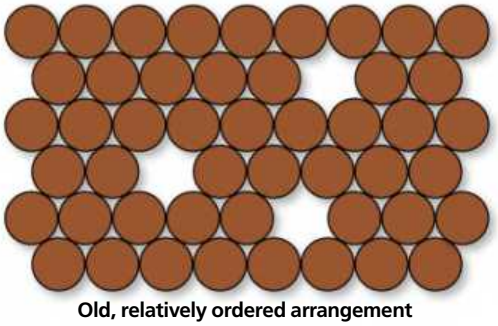
36

Randomness to Order

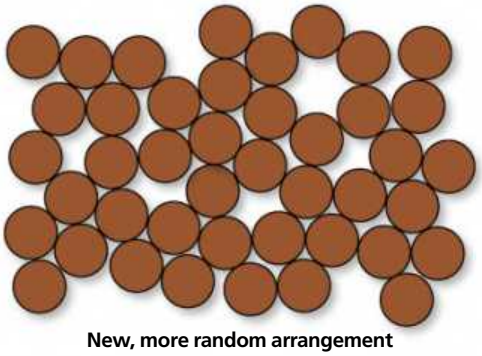
Toss a bunch of pennies flat on a table, and then push them together until they're tightly packed and can't move any closer. They'll form nearly perfect hexagons, with only an occasional spot that's more disordered. Researchers had long thought that these "relatively ordered" arrangements were the most random ones you could get in the circumstances.

But early this year, Princeton materials scientists Steven Atkinson, Frank Stillinger and Salvatore Torquato found significantly less dense configurations by pushing the pennies together as if they were on a shrinkable pad of rubber rather than a rigid table, until reaching the "no closer" point. The resulting arrangements contain few hexagons; the pennies in these new configurations touched an average of only four others.

And the results scale up: The researchers found a new mathematical method to arrange matter — not just pennies, but all particles. These new, less-dense configurations point the way toward materials with novel optical properties, particularly devices that could transmit or reflect chosen wavelengths of light by changing the density of the material. More fundamentally, the finding provides researchers a new universe of possibilities for understanding how to pack objects together. "It challenges the conventional wisdom about what randomness is," Torquato says. —JULIE REHMEYER



Old, relatively ordered arrangement



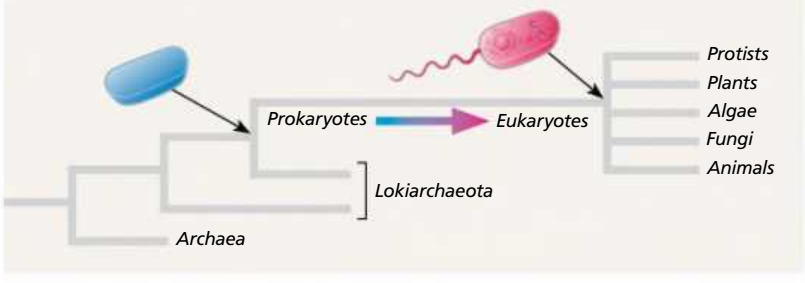
New, more random arrangement

37

On the Cusp of Complexity

When Norwegian researchers brought up a mud core from the floor of the Atlantic Ocean in 2010, they were orchestrating a family reunion. After 2 billion years of separation, a descendant of our distant common ancestor, a simple microorganism, has been discovered in the sediment by molecular biologists at Uppsala University in Sweden.

All nonviral life on Earth belongs to one of three domains. Complex organisms, distinguished by nucleated cells, collectively belong to Eukarya. The other two domains, genetically different yet both structurally simple, are Bacteria and Archaea. One of the great puzzles in biology is how simple life evolved to become complex. The Archaean discovered under the Atlantic — dubbed Lokiarchaeota in *Nature* in May — appears transitional, showing an unprecedented degree of genetic overlap with eukaryotes.



In our *very* extended family tree, Lokiarchaeota marks an important transition point in evolution: It's still simple but shares some genes with more complex organisms.

For instance, Loki has genes that are nearly identical to those used by eukaryotes to build the cellular scaffold known as the cytoskeleton. Even more notable, Loki has genes that code for proteins involved in phagocytosis, the process by which one cell can swallow another — and widely believed to be the way eukaryotes acquired mitochondria, a cell's power source.

Lead researcher Thijs Ettema was surprised to find such a close cousin in the first sample he sequenced. "This indicates that there probably is much more out there than meets the eye," he says. "Most likely we'll have to revise the biology textbooks a few more times in the near future." —JONATHON KEATS

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Regaliceratops, Wendiceratops: The Ones With Looks That Frilled

Thanks to comparatively plentiful fossils, ceratopsids — horned and frilled dinosaurs with rhinolike bodies, such as *Triceratops* — are among the best-studied dinosaurs. But there are still surprises to be found.

Consider the 68-million-year-old, nearly complete skull of *Regaliceratops peterhewsi* (left), found in Alberta, Canada, and described in *Current Biology* in June. The dinosaur has a unique frill that Royal Tyrrell Museum paleontologist Caleb Brown, part of the research team, says one fan on social media likened to "looking like the animal ripped the plates off a Stegosaurus and used them to adorn itself."

Wendiceratops pinhornensis (right), also from Alberta and described in *PLOS One* in July, has its own distinctive display: an elaborate assemblage of massive horns and a frill with dramatic, curving hooks. Paleontologists have found scores of bones from at least four individuals at a single site. The 79-million-year-old "new" dinosaur, which grew to about 20 feet long, is considered one of the earliest species of ceratopsids ever found.

Contrary to popular belief, the animals did not use their fabulous frills and horns for fighting or defense. Says Brown: "The display is a billboard that says something like, 'I'm an impressive male of Species A, and I see you're also Species A. We should herd together.' " —GEMMA TARLACH

CHAD EDWARDS

39

FDA OKs Sex Drug for Women

In August, the FDA approved Addyi, the first drug authorized to treat hypoactive sexual desire disorder (HSDD), or lack of libido. As the first such pharmaceutical designed for women, the press dubbed it Female Viagra — incorrectly, since Viagra and its cohort address the physical issue of erectile dysfunction and are taken as needed. Addyi, or flibanserin, tweaks the brain's mix of neurotransmitters dopamine and serotonin, must be taken daily and can take two months to fully kick in.

Unfortunately, the results are, um, anticlimactic. Relative to the placebo, only an additional 10 percent of women in trials had a marked response: hardly one more sexually satisfying event per month. "Not very many, in light of all of the significant side effects," worries Lori Brotto, a University of British Columbia sex researcher and a leading HSDD expert. Alcohol exacerbates these side effects, including severely low blood pressure and loss of consciousness.

And since women with conditions that often accompany HSDD, like depression, were excluded from the trial, Brotto notes that Addyi's impact on them is still unknown. Still, she believes the drug might benefit some of the roughly 10 percent of women with HSDD. The critiques of its effectiveness and side effects have triggered important discussions in the field about desire and what drives it. "I think that's a very good thing," Brotto says. —ERIK NESS

CLOCKWISE FROM TOP LEFT: AP PHOTO/ALLEN G. BREED; B. BIRD, NRAO/AUI/NSF; GONZALO FUENTES/REUTERS/CORBIS; NASA/JPL-CALTECH/SHAUN AMY

40

Green Bank Telescope

Billionaire Backs Search for Aliens

Mankind is about to move one giant leap closer to finding out if we're alone. In July, Russian entrepreneur Yuri Milner announced he would finance the most comprehensive search for extraterrestrial intelligence (SETI) ever.

The $100 million, 10-year project, called Breakthrough Listen, will examine 100 galaxies and 1 million stars for evidence of alien technology. The Green Bank Telescope in West Virginia and the Parkes Telescope in Australia will scan for radio pings from other planets, and the Automated Planet Finder in Mount Hamilton, Calif., will search for extraterrestrial lasers. All data will be public, whether they reveal aliens or just silence.

Yuri Milner (top) is financing Breakthrough Listen, a project using the Parkes Telescope (above) and others to find alien intelligence.

Opponents say we shouldn't waste money looking for beings that might not exist, and instead focus on surefire science and projects that help humans. But past SETI projects haven't searched extensively (cosmically speaking) due to financial restraints and the hugeness of the universe.

As SETI pioneer Jill Tarter likes to say, so far SETI has scooped a single glass of water from the cosmic ocean, and no one would conclude the earthly sea is fishless from a 1-cup sample. Breakthrough Listen, if nothing else, will fill more cups. —SARAH SCOLES

41

Fish Found Deep Beneath Antarctic Ice Shelf

In January, scientists in Antarctica discovered something amazing: fish living in a dark pocket of seawater under nearly a half-mile of ice.

Scientists from the University of Nebraska-Lincoln and other universities bored a hole into an isolated nook where glaciers ooze off the coast and form the massive Ross Ice Shelf, a slab of floating ice the size of Spain. The hidden spot, 500 miles in from the ice's edge, is far removed from life-sustaining sunlight, so the researchers expected to find only microbes. But when they sent down an aquatic robot, its camera revealed fish, crustaceans and other animals. It is the farthest under an ice shelf that animals have ever been found.

"It's remarkable," says James McClintock, a marine biologist from the University of Alabama at Birmingham, who was not on the expedition. "What intrigued me is, what is supporting this life?"

Left: An amphipod is measured, in millimeters, in the field lab just after it was collected beneath Antarctica's Ross Ice Shelf. Above: A remote-operated vehicle's camera captures an image of a fish living under nearly a half-mile of ice.

The ecosystem may be nourished at least in part by microbes that feed on organic goo in the subglacial mud — the remains of ancient plankton that died and sank to the bottom millions of years ago, when the world was warmer and this place was a sunlit sea.

—DOUGLAS FOX

42

Layer Cake of Nanoparticles Could Clean Up Oil Spills

Cleaning oil spills could be as easy as scraping frosting off a cake, thanks to a nanoparticle coating developed by Philip Brown and Bharat Bhushan, engineers at the Ohio State University.

Traditional chemicals that disperse oil spills can harm marine life more than the oil itself. Instead, environmentalists might one day use specially coated nets that separate oil from water. The coating, announced in March, covers a stainless steel mesh and works by first adding silica nanoparticles to create a bumpy, liquid-repelling surface.

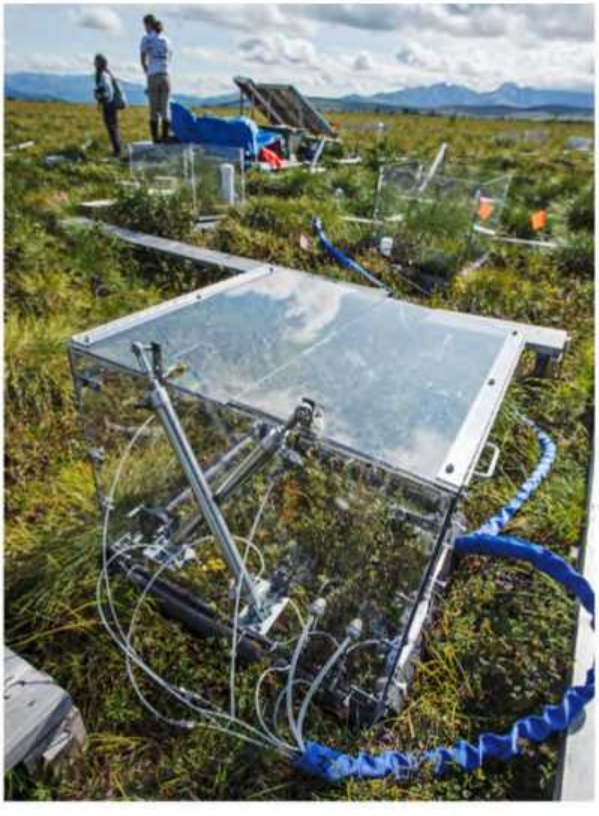
Next comes a polymer layer that acts as a binder, followed by a layer of surfactant, a molecule with two key parts: one that loves water and another that hates oil. The surfactant's different response to the two liquids allows the coated mesh to separate them. When Brown and Bhushan tested the mesh, water slid through while oil remained trapped on top.

The layered approach helps the coating components bind and function better, and the more durable the coating, the more affordable it is to scale up for major oil spills. Any way you bake it, this layer cake of tiny particles could provide durable filters for big messes. —LEAH SHAFFER

Thanks to a special coating on this stainless steel mesh, a mixture of oil and water is easily separated. The technology could be scaled up for bigger projects, such as cleaning oil spills.

TOP: REED SCHERER/NORTHERN ILLINOIS UNIVERSITY (2). BOTTOM: PHILIP S. BROWN AND BHARAT BHUSHAN/OHIO STATE UNIVERSITY

Top: A bank of thawing permafrost, about 1,400 miles from the North Pole. Bottom: In Alaska, the Carbon in Permafrost Experimental Heating Research project heats tundra in plastic chambers to study the uptake and release of carbon dioxide.



CO_2 'Time Bomb' From Thawing Permafrost More Like Slow Leak

Climatologists have long feared an Arctic "time bomb" — a sudden release of carbon dioxide from thawing permafrost soils that would trigger runaway warming. But a study released in April suggests CO_2 will escape gradually instead, providing more time to avert the catastrophic consequences.

Warming frees microbes to convert organic carbon from ancient plants into carbon dioxide. But the study, by U.S. Geological Survey researchers, reveals that much of this carbon is in complex forms that microbes consume only slowly. And permafrost often thaws into waterlogged mud that lacks the oxygen microbes need to process the carbon.

Even so, up to 100 billion tons of carbon could still escape by 2100. That's equal to 20 percent of all the carbon released from burning fossil fuels in the past 200 years. — DOUGLAS FOX

TOP: AP PHOTO/RICK BOWMER. BOTTOM: GARY BRAASCH/CORBIS

44

Saturn's Watery Moon

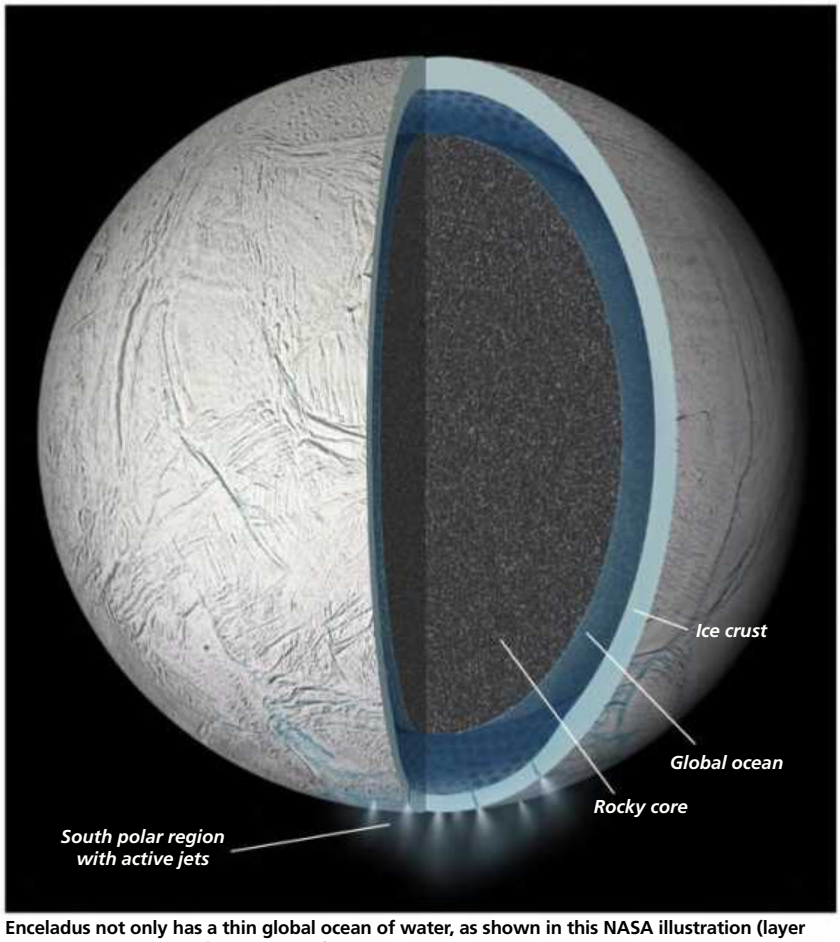
Saturn's moon Enceladus made waves in 2015 with two dramatic liquid-water-related discoveries, establishing the world as a target of great interest in the search for life.

After astronomers analyzed seven years' worth of Enceladus data from NASA's Cassini probe, they detected a slight rocking motion in the moon's rotation, suggesting an outer shell of ice.

"That could only be the case if the ice shell was not frozen to the core but separated by a layer of liquid," says team member Carolyn Porco. The team believes a shallow global ocean, perhaps only a mile deep, lies between Enceladus' rocky core and its 30-mile-thick icy crust. At the south polar region, where about 100 saltwater geysers erupt from the surface, the ocean is likely deeper and the crust thinner.

This news came on the heels of an earlier discovery, when a team of planetary scientists announced the likely presence of hydrothermal vents on the Saturnian satellite. They studied nanometer-size silicate particles in one of Saturn's rings that had originated deep in Enceladus' south pole. The analysis suggested the size and composition of the particles meant they must have been dissolved from wet rocks at least 90 degrees Celsius, suggesting hydrothermal activity — warm water.

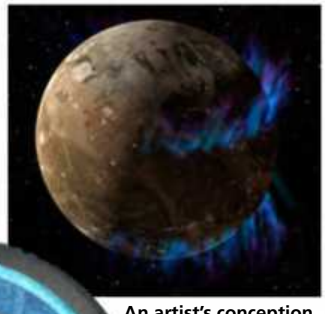
Enceladus was already a prime spot to look for life, and these new detections only make it a more enticing destination. — LIZ KRUESI



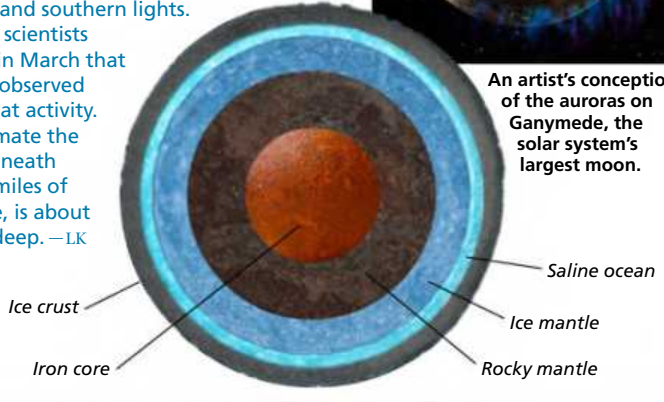
Enceladus not only has a thin global ocean of water, as shown in this NASA illustration (layer thickness is not to scale), but some of the water is likely heated via hydrothermal vents.

Another Global Ocean

Another 2015 finding confirms that Jupiter's moon Ganymede hides its own salty global ocean below a frozen rock crust, as was long suspected. Such a world-spanning saltwater ocean would be electrically conductive, producing telltale activity in Ganymede's auroras, the equivalent of our northern and southern lights. Planetary scientists revealed in March that they had observed exactly that activity. They estimate the ocean, beneath some 95 miles of mostly ice, is about 60 miles deep. — LK



An artist's conception of the auroras on Ganymede, the solar system's largest moon.



FROM TOP: NASA/JPL-CALTECH; NASA/ESA/G. BACON (STSCI); NASA/ESA/A. FEILD (STSCI)

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45

5 Small Wild Things Make Their World Debut

Discovering a new species is never easy. But it's especially difficult when the species in question is relatively rare — and smaller than a breadbox. Yet sharp-eyed scientists found several Lilliputian species in 2015, including these five. —BRENDA POPPY

1. FROM HISPANIOLA WITH LOVE

Bond. James Bond. Well, *Plagiodontia aedium bondi,* to be precise. Scientists found this cat-size mammal on the Caribbean island Hispaniola and named it after ornithologist James Bond (007's namesake).

2. PLANT POWER

Sirdavidia solannona, a flowering custard apple species discovered in Gabon, Africa, has it all: vibrant colors, a prime location in a national park and even its own genus. It's named after Sir David Attenborough, the naturalist known for the BBC series *The Hunt*, *Life on Earth* and *The Living Planet*.

3. PRIMITIVELY PERFECT

This coin-size Australian moth with iridescent wings retains features from primitive moths, and its entire adult life spans a single day. Scientists named this tiny enigma *Aenigmatinea glatzella*.

4. THE LONER

Capelatus prykei, a 0.3-inch diving beetle found in Cape Town wetlands, is an orphan of a bug, earning it its own genus. Its closest kin live thousands of miles away and haven't shared an ancestor for at least 30 million years.

5. IT'S NOT EASY BEING TRANSPARENT

Kermit the Frog has a 1-inch doppelganger in the Costa Rican glass frog species *Hyalinobatrachium dianae*. But this tiny frog's belly is transparent, revealing its organs.

CLOCKWISE FROM TOP LEFT: THOMAS COUVREUR, IRD; JOSE NUNEZ-MINO; YOU NING SO/CSIRO; BRIAN KUBICK! (2); DAVID BILTON/PLYMOUTH UNIVERSITY

46

Stamping Out Superbugs

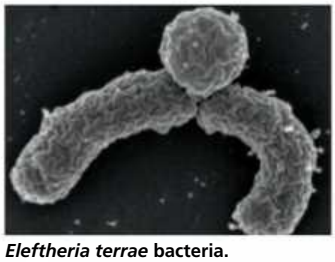
In January, scientists discovered a potential new class of antibiotic — by digging through dirt.

Soil microorganisms secrete much-desired antimicrobial compounds that yield novel drugs, but they're fickle: Ninety-nine percent of microbial species won't grow in labs. So Kim Lewis' team at Northeastern University in Boston devised a method to isolate microbes in their natural environment to test their therapeutic potential.

After screening more than 10,000 soil bacteria samples, they identified *Eleftheria terrae,* which deploys the chemical teixobactin. In tests on mice, teixobactin obliterated drug-resistant bacteria — and target cells didn't develop resistance to it. In fact, Lewis says it's unlikely bacteria could engineer defenses against teixobactin within 40 years, if at all.

The timing couldn't be better. Unless our antibiotics arsenal expands, drug-resistant infections could kill more people globally than cancer by 2050, some experts say.

It will be a few years before teixobactin moves to human trials, but Lewis' method of studying previously uncultivable soil bacteria is a new twist that could reignite our search for antibiotics. — CARL ENGELKING



***Eleftheria terrae* bacteria.**

FROM TOP: HAGAI PERETS; NASA/JSC; WILLIAM FOWLE/NORTHEASTERN UNIVERSITY

47

Scientists think the body that smashed into a nascent Earth, and eventually became the moon, was likely made of the same materials as our planet.

The Moon's Violent Birth

The origin of Earth's abnormally large moon is a long-standing mystery in astronomy. Most scientists believe our satellite formed from the remains of a small world called Theia after it smacked into Earth 4.5 billion years ago. Models show that chunks of the Mars-size interloper spun off and coalesced into the moon. So astronomers were puzzled when lunar samples returned by Apollo astronauts showed striking similarities to Earth rocks instead.

A moon rock recovered during the Apollo 16 mission puzzled researchers initially because its composition of a rare metal is identical to Earth's.

In April, astrophysicists announced they'd found a possible reason: Theia was Earth's twin. In a *Nature* study, scientists modeled the solar system's birth and watched virtual worlds collide like wrecking balls. They found that Theia likely formed close to Earth and collected the same cosmic debris as it grew. It makes sense, then, that the moon, as a spinoff of Earth-like Theia, is made from the same stuff as our planet.

But that doesn't tell the whole story, according to a University of Maryland study published the same month. Exploring why Earth and its moon both contain the same isotopes of the rare metal tungsten — something that couldn't be explained by the Theia collision theory — the researchers' model showed that after the moon formed, other nearby collisions blasted tungsten-containing debris onto both Earth and the newborn moon. — ERIC BETZ

48

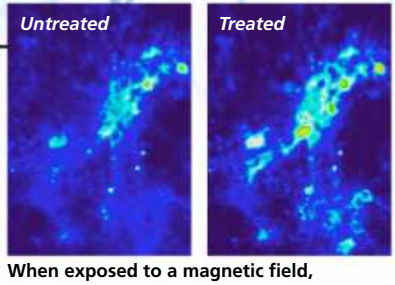
Remote-Controlled Brain

Internet connections can be wireless, so why shouldn't brain medicine be? Stimulating neurons deep within the brain can help treat conditions such as Parkinson's disease and obsessive-compulsive disorder, but right now patients must undergo invasive electrode implants. In 2015, two research teams announced they found a way to skip the implants and stimulate the brain remotely.

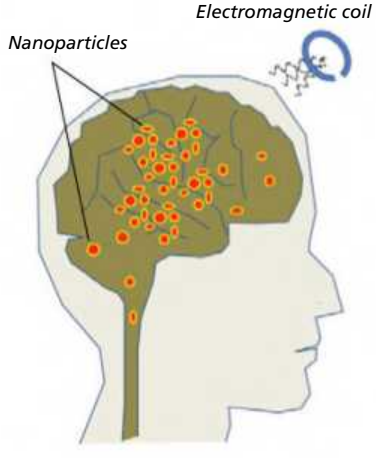
Hot, Hot, Hot

In March, MIT materials scientist Polina Anikeeva and her team announced they'd heated things up by injecting a specially engineered virus that carried a gene for heat sensitivity — the same one that gives us a "hot" sensation when we eat chili peppers — into a region of mouse brain. Once the virus infected neurons with the heat-sensing gene, the researchers injected magnetic nanoparticles into the same brain cells. When they exposed the mouse to a magnetic field, the nanoparticles warmed up, and the now heat-sensitive neurons fired.

A month later, the nanoparticles remained, able to stimulate the neurons. Next, the group plans to study how this stimulation affects the animal's behavior — a step toward use in humans.



When exposed to a magnetic field, injected magnetic nanoparticles heat up and cause neurons carrying a gene for heat sensitivity to fire (shown in yellow, white, green and light blue at right). Untreated neurons (left) show less activity.



A magnet pulled "smart" nanoparticles through a mouse's bloodstream into its brain, similar to this figure. Once a weak magnetic field was present, the nanoparticles triggered the neurons.

Playing It Smart

Scientists from Florida International University and the University of California, Riverside skipped the heat and got smart when they announced another wireless stimulation method in July. Engineer and immunologist Sakhrat Khizroev and his colleagues excited neurons using "smart" nanoparticles, which generate a local electrical field when exposed to a magnetic one. They injected the nanoparticles into a mouse's bloodstream through its tail. Then, they held a strong magnet above the mouse's head to drag the particles upward through the blood-brain barrier, a filter that normally keeps unwanted molecules out of the brain. Once the nanoparticles squeezed through the barrier and the mouse was exposed to a weak magnetic field, the critter's brain responded by firing electrical signals.

Khizroev used the tail-to-head trick to spread the nanoparticles through the brain and mimic IV drug delivery in humans. But later, he says targeted magnetic fields could focus the treatment. He envisions the particles as multitaskers, delivering drugs *and* stimulating neurons. No wires needed. — ELIZABETH PRESTON

FROM TOP: SEBASTIAN KAULITZKI/SHUTTERSTOCK; POLINA ANIKEEVA ET AL./MIT MCGOVERN INSTITUTE FOR BRAIN RESEARCH/DARPA/NSF; COURTESY SAKHRAT KHIZROEV/FLORIDA INTERNATIONAL UNIVERSITY

A 'Quarky' Quintet

49

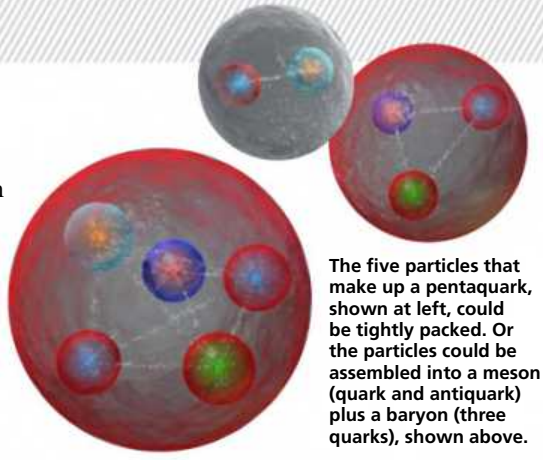
The world at scales smaller than a proton is strange — one might even say "quarky."

Quarks are fundamental particles that come in six flavors — yes, that's the official term — which also have antimatter equivalents. They're never found alone, but nearly always in pairs (called mesons) or trios (called baryons), which include protons and neutrons. Four-quark particles, tetraquarks, have been observed only in particle collider experiments.

Naturally, physicists were surprised when they detected two different particles with five quarks.

The July announcement of these pentaquarks came from the Large Hadron Collider — the world's largest particle accelerator, located in a 17-mile tunnel under the French-Swiss border. The LHCb experiment, which specifically looks at the behaviors of particles containing "bottom" flavored quarks (also called "beauty," which is what the "b" stands for in LHCb), made the discovery.

The pentaquark discoveries represent a new, exotic form of matter that scientists don't entirely understand yet. The particles lived for a tiny fraction of a second before disintegrating, but that's enough to give scientists a new puzzle to ponder. —ELIZABETH LANDAU



The five particles that make up a pentaquark, shown at left, could be tightly packed. Or the particles could be assembled into a meson (quark and antiquark) plus a baryon (three quarks), shown above.

The LHCb magnet, shown under construction in 2008, studies bottom quarks and was responsible for revealing the pentaquark.

Drinking Up Math's Moonshine

50

In the late 1970s, two mathematicians, John Conway and Simon Norton, saw a deep connection between two mathematical objects that should have nothing to do with each other. On one side of the link was a fundamental object in number theory called the j-function. On the other was a mysterious entity that described a new kind of symmetry, but might not even exist. If it did, though, it would be enormous ($8x10^{53}$ components), so they dubbed it the "monster group." The connection sounded so crazy, Conway and Norton called their theory "monstrous moonshine."

In 1992, Richard Borcherds proved monstrous moonshine: He found the link between the monster group (which does exist) and the j-function through string theory, the idea that the universe is made of tiny strings vibrating in high dimensions. But monstrous moonshine, it turns out, was just the beginning.

In March, John Duncan, Michael Griffin and Ken Ono proved 23 other moonshine-like correspondences between groups like the monster group and functions like the j-function, a conjecture dubbed "umbral moonshine." It's most likely all of these connections are also made through string theory, which may lead to even bigger game. "The ultimate goal," Duncan says, "is to unify quantum mechanics and Einstein's theory of gravity. That's a very, very big goal for physics, one of the biggest goals in science." —JULIE REHMEYER

FROM TOP: DANIEL DOMINGUEZ/CERN; PETER GINTER/CERN

51

Chronic Fatigue Syndrome Gets Some Respect

In 2006, I staggered into a neurologist's examining room. The previous week, my legs seemed stuck to the floor, and I strained mightily to lift them. I couldn't tell whether my muscles were suddenly too weak to raise my feet, or whether the signal to move was getting lost as it traveled from my brain to my legs. Whatever was happening, I needed help.

The neurologist's diagnosis: chronic fatigue syndrome.

After I recovered from my incredulity — *fatigue?* — I asked him about tests, treatments and specialists. He had nothing to suggest. For him, chronic fatigue syndrome meant, "I can't help you."

Such experiences are nearly universal among the 1 million patients with chronic fatigue syndrome in America. Far more than just being tired constantly, they also suffer from neurological problems, an inability to regulate blood pressure when standing, worsened symptoms after exercise and immune problems. Rest doesn't help, and the illness is more debilitating than heart failure or multiple sclerosis.

Nevertheless, CFS (called myalgic encephalomyelitis internationally and often abbreviated ME/CFS) has received little research funding — $5 million a year compared with more than $100 million for multiple sclerosis, a similar disease. There is no simple diagnostic test for the illness, and as a result, doctors are often skeptical it's real and serious, despite substantial and growing evidence for biological abnormalities in patients.

There are signs of change, however. In February, the Institute of Medicine, a private nonprofit group that advises the government on health issues, released an authoritative report on ME/CFS, exhorting doctors to take it seriously. It also developed new diagnosis criteria and recommended a new name, contending that the name *chronic fatigue syndrome* is misleading and trivializing.

A few weeks later, Ian Lipkin and Mady Hornig, physician-scientists at the Columbia University Mailman School of Public Health, published the largest study of the immune systems of ME/CFS patients yet, with 298 patients and 348 healthy controls. It showed immune systems of relatively newly ill patients were revved up, like they'd just detected a new infection. But the immune systems of patients who'd been sick for more than three years appeared exhausted — a distinction never seen before.

"We see it not only as a way to help with differential diagnosis," Hornig says, "but also to perhaps open up avenues for treatment." The pattern of immune changes might distinguish ME/CFS patients from those with other diseases, eventually leading to a blood test to diagnose the illness.

And in July, Øystein Fluge and Olav Mella of the University of Bergen in Norway published a small study bolstering evidence that the cancer drug rituximab can treat ME/CFS, in which about two-thirds of patients benefited notably. Rituximab kills off B cells, a type of immune cell implicated in some autoimmune conditions.

These new developments are just the beginning in unraveling the disease, and patients and researchers alike agree that more funding is essential to developing tests and treatments. Patients like me certainly hope it's coming.

—JULIE REHMEYER

ALDO MURILLO/ISTOCK

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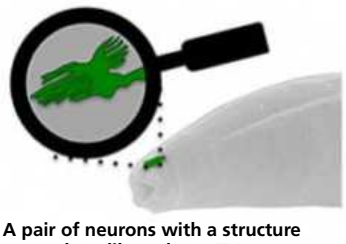
Why Worms Don't Wander

Many animals use Earth's magnetic field for navigation, but exactly how they detect it has been a puzzle — until now.

For the first time, researchers at the University of Texas at Austin have pinpointed a specific pair of neurons that act as a magnetic sensor in the simple worm *C. elegans*. The neurons function as an internal compass, giving the worm a sense of up and down, likely to help them find food, which varies in availability and quality at different soil depths.

By adding a fluorescent marker to the neurons, researchers could watch the pair light up when exposed to magnetic fields. They also observed that hungry worms burrowed downward, where food was likely to be more plentiful in their natural environment, even when they were in a lab setting where no food was present. The worms did this, however, only in the presence of Earth's magnetic field. The worms would wander aimlessly if researchers either shut down the specific pair of neurons or artificially canceled the magnetic field.

These findings, published in *eLife* in June, could help uncover how more complex animals, such as birds, pick up Earth's magnetic field. — ANDY BERGER



A pair of neurons with a structure researchers likened to a TV antenna (inset) help *C. elegans* worms find food using Earth's magnetic field.

CLOCKWISE FROM TOP: UNIVERSITY OF THE WITWATERSRAND; PURDUE UNIVERSITY; ANDRES VIDAL-GADEA

53

The Age of Little Foot

Entombed for millions of years deep within South Africa's Sterkfontein Cave, one of the most complete early hominin fossils ever discovered is reshuffling our family tree.

Nicknamed Little Foot for its modest size, the skeleton was estimated to be 2.2 million to 3 million years old. More accurate dating of the sediment in which the fossil was found, however, establishes that it's 3.67 million years old.

More accurate dating places the hominin Little Foot much earlier in our family tree.

Until now, Little Foot was considered a more recent species than Lucy, the famous 3.2-million-year-old *Australopithecus afarensis* from Ethiopia often cited as our direct ancestor. But Little Foot's new age, published in *Nature* in April, suggests that hominin diversity and range was much greater much earlier than we previously thought.

Some researchers have classified Little Foot as *A. africanus*, a later australopith found only in South Africa. But Ronald Clarke, who has been studying Little Foot since the 1990s, thinks the hominin should be called *A. prometheus*. His view is gaining momentum now that the more accurate date establishes Little Foot to be much older than other *A. africanus* finds.

Whatever we ultimately call the skeleton, Little Foot raises questions about which australopiths are our direct ancestors — and which are merely relatives. — RUSS JUSKALIAN

Excavated from Sterkfontein Cave over more than a decade, Little Foot is the oldest hominin fossil — and one of the most complete — ever found in South Africa.

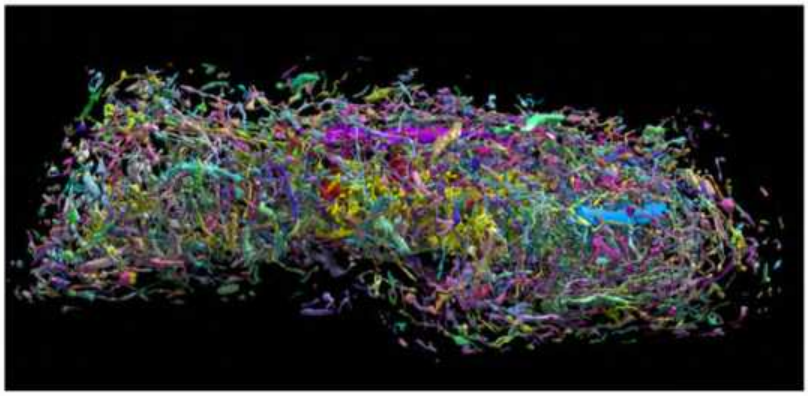
54

A Mighty (Small) Mouse Brain Map

"It is a little pathetic," says Harvard neurobiologist Jeff Lichtman, looking at a dense 3-D map of a mouse's neocortex. It took six years and 20 other researchers to complete the model — the most detailed brain reconstruction to date. Yet it represents a measly several billionths of a mouse brain.

To achieve their "pathetic" accomplishment, which was published in July in *Cell*, researchers fed a brain chunk about as big as a grain of sand through a machine that sliced it vanishingly thin. That machine then stuck the slices to a plastic tape to create a sort of film reel of the chunk. A scanning electron microscope captured each frame digitally so researchers could use computers to trace what they saw. Then, focusing on an invisibly small, more manageable portion of their sample, they accounted for every cellular detail of each frame.

The resulting map includes every branch of every neuron, their mitochondria and supporting cells. The scientists created a spreadsheet giving locations of the 1,700 synapses (connections between neurons) plus which neurons they joined, and other data.



A view of the incredibly detailed reconstruction of a minuscule chunk of mouse brain shows how dense the brain is (right). An exploded view (above) shows the connections better.

A surprise emerged in how neurons' branched arms connect with each other: Instead of synapsing with their conveniently close neighbors, as previously thought, two branches may seek each other out repeatedly amid the thicket of other cells. These deliberately reinforced connections might represent learning, Lichtman speculates. He hopes to learn more about the brain's wiring in his next project: a map of an entire cubic millimeter. — ELIZABETH PRESTON

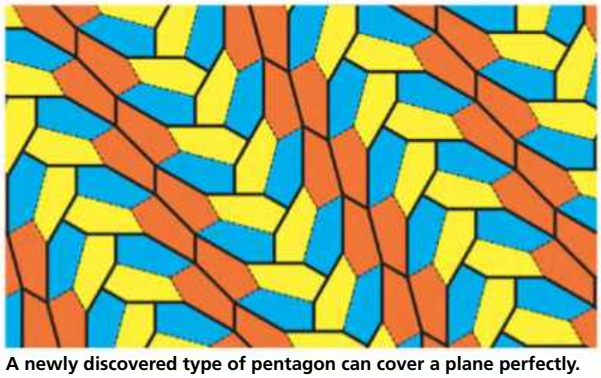
55

Pentagon Puzzler

Here's a puzzle for you: Take a bunch of pentagons and try to fit them together so that they cover a tabletop perfectly, with no gaps or overlaps. If you try it with ordinary pentagons, with equal sides, you'll soon see it just won't work. But loosen the requirements by allowing unequal sides, and all becomes possible. Mathematicians had found 14 different types of pentagons that worked, but for 30 years, no one could find another.

In August, mathematicians Casey Mann, Jennifer McLoud-Mann and David Von Derau of the University of Washington in Bothell discovered a 15th. They developed a clever computer algorithm to sort through all the possible configurations to find one that fit.

The new pattern is certain to inspire fresh mathematical art, but additionally, tiling problems like this connect richly to other areas of mathematics. Not only does the new pentagon give bathroom floor decorators new possibilities, scientists could create a new material with novel properties that use this pattern at a molecular level. — JULIE REHMEYER



A newly discovered type of pentagon can cover a plane perfectly.

FROM TOP: DANIEL BERGER, NARAYANAN KASTHURI AND JEFF LICHTMAN, HARVARD UNIVERSITY (2); ALPTRAUM/ISTOCK; CASEY MANN

Visually stunning and very steamy, Yellowstone's Grand Prismatic Spring is one of many hydrothermal features the park owes to the massive supervolcano beneath it.

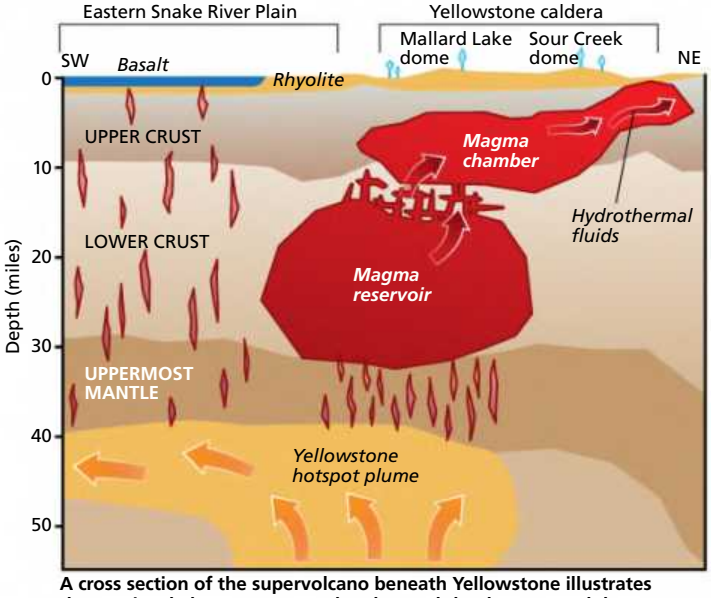
Supervolcano Supersized

Whoa. There's a *lot* more magma under Yellowstone National Park than we thought. How much? Enough to fill the 1,000-cubic-mile Grand Canyon 11 times over.

University of Utah researchers recently combined data from seismographs near and far to visualize Yellowstone's magma more precisely. In the past, seismology stations in Wyoming and adjacent states have provided information on a shallow chamber of magma beneath Yellowstone. But by incorporating data from more distant stations as well, seismologists could take a deeper look at the volcano, and they found a much larger body of magma beneath the known chamber.

According to the findings published in *Science* in April, cross sections of the newly discovered magma body reveal it's more than four times larger than the one on top of it, making Yellowstone one of the largest volcanic sites on the planet.

The new find doesn't make the supervolcano any more dangerous, however. The reservoir has been there for millennia and is not getting bigger — the only thing that has changed is our awareness of it. And although there have been major eruptions at Yellowstone, most recently 640,000 years ago, Utah geophysicist Robert Smith puts the odds for a major eruption at 1 in 700,000 during any given year. — JIM SULLIVAN



A cross section of the supervolcano beneath Yellowstone illustrates the previously known magma chamber and the deeper, much larger magma reservoir discovered through new imaging techniques.

TOP: "WINDOWS INTO THE EARTH," ROBERT B. SMITH AND LEE J. SIEGEL. BOTTOM: HSIN-HUA HUANG, UNIVERSITY OF UTAH

57

Mind Reading at a Higher Level

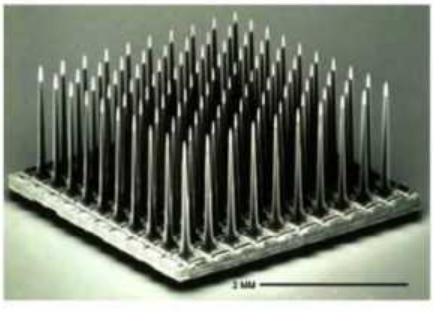
People with paralysis or an amputation can already use their minds to control robotic limbs, helping to restore their sense of independence, but the motions are often clumsy and unnatural. Researchers announced in May that they created a neural prosthetic that gives those with artificial limbs finer, smoother movements.

Standard neural prosthetics ferry signals from the brain's motion control center, the motor cortex, to a cable connected to a computer controlling the limb. These signals break down a physical task into individual movements — like listing the steps involved in grabbing your coffee mug. But this team went further upstream in the brain's signaling chain and used signals from a patient's posterior parietal cortex (PPC).

The PPC is where your brain determines "the goal of the movement," says principal investigator Richard Andersen of Caltech. In other words: "I want to grab my coffee."

After surgeons implanted the prosthetic in a quadriplegic patient, he could use a robotic arm to shake someone's hand and even hold a glass steady enough to drink from it on his own.

Next up: Anderson plans to integrate touch and position sensations. —LACY SCHLEY



Erik Sorto enlists a brain-controlled robotic arm to help himself to a drink. Researchers use an fMRI scan (above) to place a pair of small electrode arrays in the brain. Each electrode in the array (below) records the activity of a single neuron. A system of computers processes the signals, decoding the person's intent.

FROM LEFT: SPENCER KELLIS AND CHRISTIAN KLAES/CALTECH; CALTECH (2)

58

Meet the First Warmblooded Fish

The discovery of a warm-blooded fish, announced in May in the journal *Science*, was no fisherman's tale.

The opah, or moonfish (*Lampris guttatus*), with small fins relative to its big, disk-shaped body, seems an odd candidate for warmbloodedness: The deep-sea fish has lots of surface area for heat loss and definitely isn't shaped for speed. But the opah generates heat by continually flapping those fins, says the study's lead author, Nick Wegner, a fisheries biologist with the National Oceanic and Atmospheric Administration in La Jolla, Calif.

The opah's adaptation gives it an advantage over other predators in cold depths.

Fatty connective tissues around the opah's muscles and fat layers around its organs — particularly the heart — help retain heat. Veins carrying warm blood from the heart to the gills interweave with arteries bringing colder, oxygen-rich blood from respiration. Heat exchange occurs between blood vessels in the gills, which are exposed to cold water.

The opah's ability to maintain its body slightly above ambient temperatures gives it advantages over the slower, colder prey it hunts. "Their warmer heart provides muscles with oxygen and nutrients. They swim faster and with more power," says Wegner.

Tuna, marlin and great white sharks heat up certain areas — swimming muscles, parts of their viscera and the eye and brain — but these regional endotherms can stay at lower depths only for short periods and must rise to warmer waters, unlike the deep-dwelling opah.

No other known fish has such an adaptation, though Wegner notes the opah has a cousin, the southern opah (*Lampris immaculatus*), in the Southern Hemisphere. "We would expect it's using the same strategy," he says. —JAMES MCCOMMONS

59

Galactic Gains

Two rings of stars once thought outside our galaxy might actually be part of it and would extend the disk 50 percent farther from its edge.

The starry disk that is our galaxy may extend at least 50 percent farther from its apparent edge than we thought. Instead of being flat, the Milky Way appears grooved like a vinyl record, upping its width to at least 150,000 light-years, researchers now say.

In 2002 and 2004, astronomers found two rings of stars, Monoceros and Triangulum Andromeda, beyond the disk's known edge. But this new study, published in *The Astrophysical Journal* in March, suggests that what looked like the disk's edge is just a deep groove, and the two apparent stellar rings are actually part of the disk.

Study co-author Heidi Jo Newberg of Rensselaer Polytechnic Institute in Troy, N.Y., and colleagues believe the grooves might be caused by one or more small galaxies, or galaxy-size nuggets of dark matter, being gravitationally dunked into the Milky Way, like stones thrown into water. —MAGGIE MCKEE

TOP: RALPH PACE. BOTTOM: DANA BERRY/RENSSELAER POLYTECHNIC INSTITUTE

Solar-Powered Flight Sets Records, Grounds Plane

60

Above: After almost five days in the air, Solar Impulse 2 landed in Honolulu. Right: Project co-founder Bertrand Piccard (left) greets pilot and co-founder André Borschbergin in Hawaii. Below: The record-setting flight began in Nagoya, Japan.

Powered by nothing but the sun, the Solar Impulse 2 aircraft set several records — including longest solar aviation flight *and* longest solo flight. Pilot and project co-founder André Borschberg landed the plane in Hawaii on July 3 after nearly 118 hours in the air. With no emergency landing sites on the trans-Pacific route from Japan, this was the riskiest leg of a round-the-globe expedition designed to showcase the promise of clean, renewable energy. Unfortunately, the plane's batteries severely overheated during the flight, grounding the remainder of the voyage until 2016. —ANDY BERGER

ALL IMAGES: SOLAR IMPULSE/JEAN REVILLARD/REZO.CH

61

Pulanesaura: The One That Put Four on the Floor

Long-necked, massive sauropod dinosaurs like Brontosaurus, towering "cows" of the Late Jurassic, didn't start out that way. Their predecessors were small and walked on two legs. South Africa's *Pulanesaura eocollum*, which lived about 190 million years ago during the Early Jurassic, gives us a peek at that transition: One of the earliest sauropods, it's the first with anatomy that shows it walked on all four legs. At about 26 feet long, *Pulanesaura* was petite compared with later sauropods and had a relatively short neck, but one with greater flexibility than its bipedal ancestors. Its neck physiology, which has hallmarks of later, larger kin, indicates that it was a low browser, sweeping its head back and forth, unlike its close relatives — living at about the same time and in the same general location — which stood on their back legs and gathered food with their forelimbs. *Pulanesaura*, says paleontologist Blair McPhee, lead author of the August study describing the dinosaur, suggests sauropods evolved to exploit untapped food sources. "The story," says McPhee, "is really the idea of dividing resources." —GEMMA TARLACH

CHAD EDWARDS

Blame It on the Iron Rain

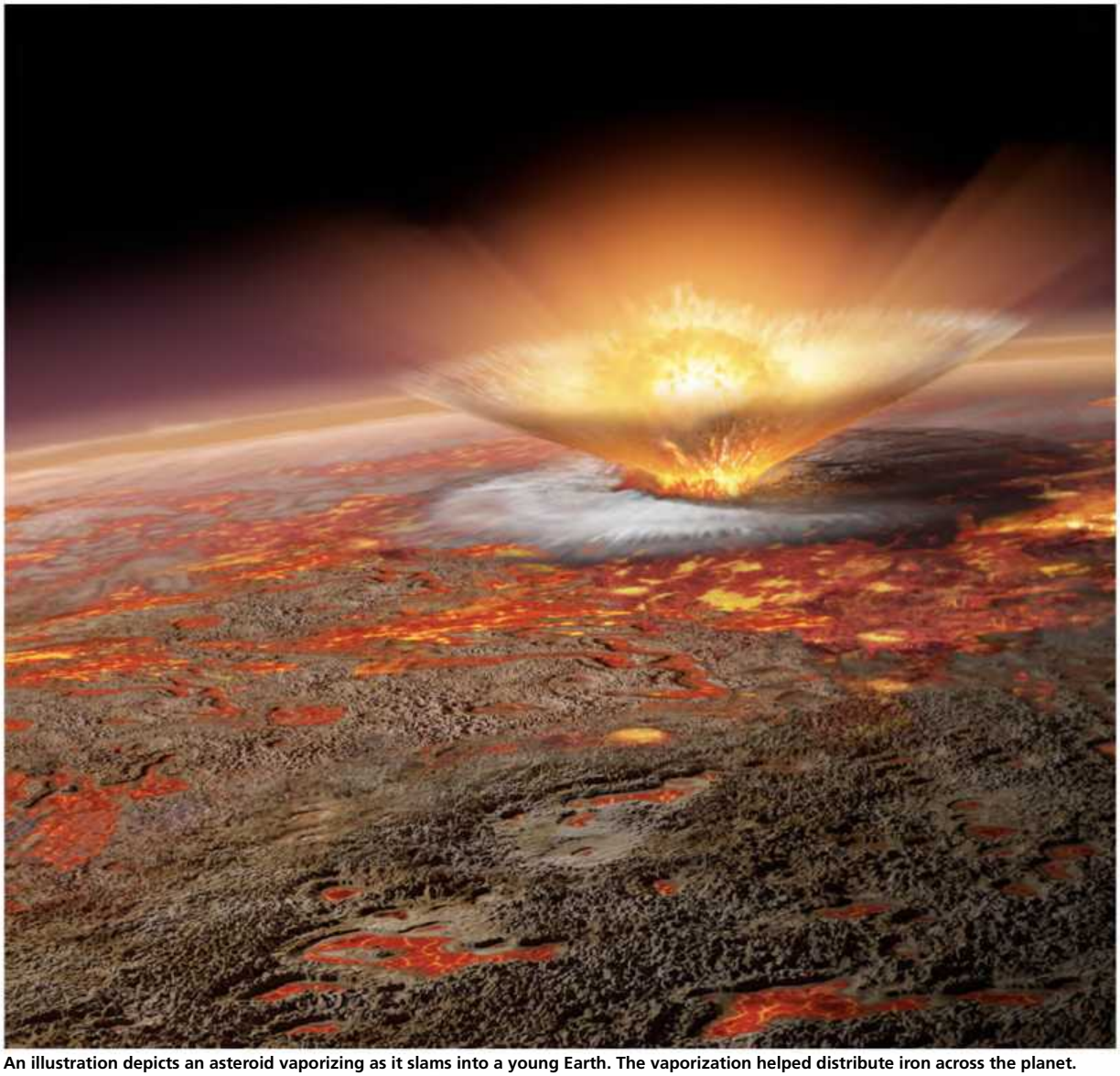
62

Early Earth was a violent place. City-size planetesimals — rocky microworlds that clumped together in the solar nebula — smashed into our planet's surface at incredible velocities and seeped down to Earth's iron core, depositing yet more iron. But now it appears that iron is instead spattered throughout our world's mantle.

To figure out how this happened, Harvard University planetary scientists paired with researchers working at Sandia National Laboratories' Z machine and shot metal projectiles into tiny iron squares at up to 55,000 mph.

Through these impacts, researchers discovered that iron vaporizes much easier than scientists had assumed. Instead of sinking into the core, iron-rich planetesimals vaporized on impact and spread out across the planet. This iron rain explains the element's distribution.

"We did not expect to find that at all. We were very surprised based on the fact that previous models people used for planet formation suggested a much higher critical shock pressure," says Richard Kraus, now a scientist at Lawrence Livermore National Laboratory and lead author on the paper published in March in *Nature Geoscience*. — ERIC BETZ



DON DIXON/COSMOGRAPHICA.COM

An illustration depicts an asteroid vaporizing as it slams into a young Earth. The vaporization helped distribute iron across the planet.

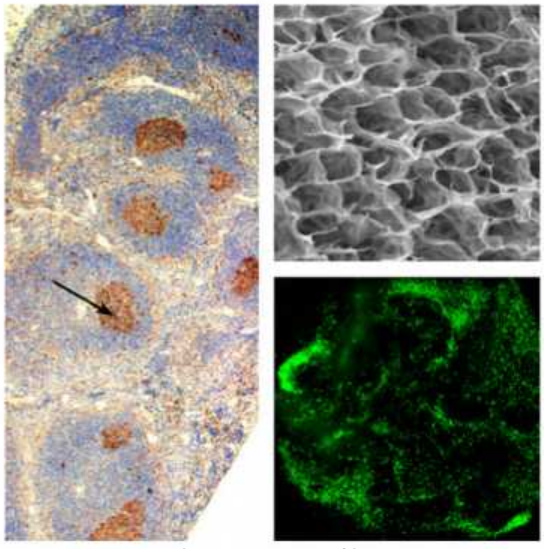
63

B Cell Breakthrough

In a first, engineers have invented artificial immune tissues that can produce antibodies. Made from gelatin-based biomaterials and seeded with living cells, the synthetic organoid mimics lymph nodes and stimulates B cells, according to a June study in *Biomaterials*. B cells swing into action when the body is under attack, generating antibodies and fine-tuning them to fight specific infections.

The immune organoid is up to 10 times more efficient than the current method of culturing cells in a petri dish. The potential applications for this platform, which could eventually eliminate the need to do immune system animal research, include tracking how blood cancers develop when B cells go haywire and devising new therapies to attack other cancers. The organoid could also help researchers design vaccines by exposing the B cells to viruses that cause HIV, Ebola and other infectious diseases, and coaxing them to generate targeted antibodies.

—LINDA MARSA



Both natural B cells (brown spots at left) and synthetic immune tissue (top right) produce antibodies. B cell activity is visible in green in the synthetic tissue (bottom right).

64

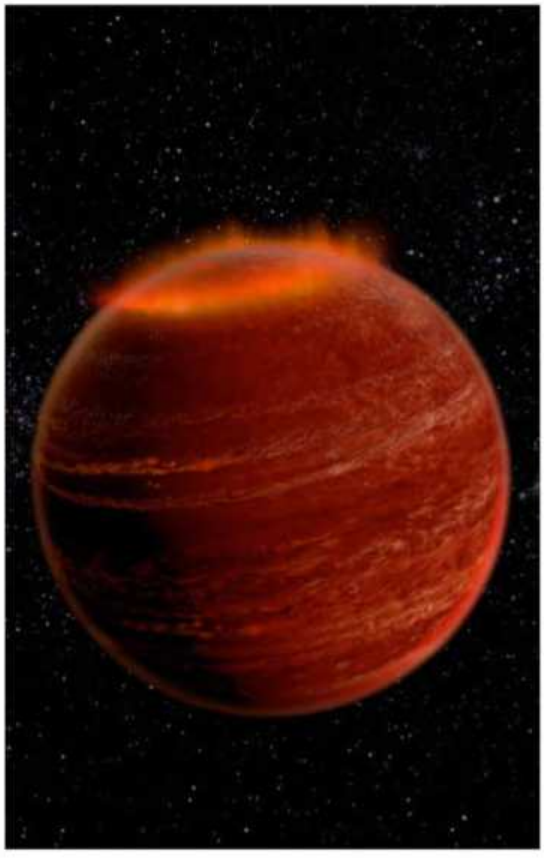
Alien Aurora

For the first time, astronomers have spotted an aurora, akin to our northern and southern lights, shimmering on a world outside our solar system. The find may bolster the search for extraterrestrial life, since the magnetic fields that drive auroras likely keep planets habitable.

Every planet in our solar system (and even some moons) with a moderate magnetic field boasts these celestial light shows. They occur when charged space particles, typically from the sun, stream along a planet's magnetic field lines and interact with atmospheric atoms, producing not only optical light but also radio emissions.

Gregg Hallinan of the California Institute of Technology and colleagues have detected both types of radiation from what appears to be a brown dwarf, an object that straddles the boundary between planet and star. The world's aurora, reported in *Nature* in July as about a million times brighter than Earth's, suggests that brown dwarfs have magnetic activity more like planets than stars. Hallinan hopes more observations shed light on the origins of the charged particles that power the aurora, which are currently unknown.

The brown dwarf in question, called LSR J1835+3259, lies 18 light-years away, suggesting astronomers may soon glimpse auroras on similarly distant planets, too. That could help narrow the search for habitable planets, since the auroras reveal the strength of their planets' magnetic fields, which can shield against harmful stellar radiation and help retain life-friendly conditions. —MAGGIE MCKEE



FROM TOP: SINGH LAB/CORNELL UNIVERSITY (3); CHUCK CARTER AND GREGG HALLINAN, CALTECH

Meet Lucy's Neighbor

Some 40 years after the famous "Lucy" fossils were discovered, jawbones and teeth from another hominin species that lived at roughly the same time, and in the same area, have been uncovered in the Afar region of Ethiopia.

Announced in May in *Nature*, the newly named *Australopithecus deyiremeda* lived between 3.3 million and 3.5 million years ago — more than 500,000 years before the first members of the *Homo* genus but as little as 100,000 years before Lucy, a member of *A. afarensis*.

Fossils from another hominin contemporary — *Kenyanthropus platyops* — were found in 1999 a few hundred miles to the south, in Kenya. A fourth hominin from the same period, *A. bahrelghazali*, was found in 1995 in Chad, more than a thousand miles to the west, although some researchers dispute the idea that all the fossils represent separate species.

But *A. deyiremeda* and its neighbors do indicate that hominins with ape-size brains had developed successful adaptations to different environments, says the study's lead author Yohannes Haile-Selassie, a paleoanthropologist at the Cleveland Museum of Natural History. Like many of his colleagues, Haile-Selassie believes the fossils come from different species; which one of them evolved into our genus is a question that can only be answered through more discoveries. —ZACH ZORICH

The partial jaw of new hominin *Australopithecus deyiremeda* (top) was found about 20 miles from the famous "Lucy" fossils by paleoanthropologist Yohannes Haile-Selassie (above).

FROM TOP: YOHANNES HAILE-SELASSIE AND LAURA DEMPSEY/CLEVELAND MUSEUM OF NATURAL HISTORY (2); STEFAN ALFONSO/ISTOCK AND DAN BISHOP/DISCOVER

66

One Little Gene Could Explain Our Big Brains

Our brains are triple the size of more primitive primates, thanks to our large neocortex. Packed with neurons, it regulates reason, cognition and language in ways that make us human. In February, German scientists identified a uniquely human gene that might have triggered our brain's evolutionary expansion.

Neurobiologist Marta Florio and her team made the discovery while studying a type of neural stem cell that forms neurons when embryos develop. They knew this cell divides many times in humans but only once in mice. To find out why, they examined genes in both mice and humans that turned on during peak brain development and spotted a DNA snippet, *ARHGAP11B*, that was active only in humans. When they smuggled *ARHGAP11B* into mice embryos, the rodent's neural development skyrocketed, indicating it was a growth driver.

The team found that *ARHGAP11B* was also present in Neanderthals and Denisovans, human cousins with similarly sized brains, but not in chimpanzees, with which we share 99 percent of our genome — further support for the idea that this gene could explain our unusually large human brains. —LINDA MARSA

The human-specific gene *ARHGAP11B* is expressed only in the right half of this embryonic mouse cerebral cortex. The folded right side shows the increased surface area caused by introducing the gene, compared with the smooth left side.

67

How Oxytocin Changes Behavior

Oxytocin cements the bond between mother and child, and even between lovers. But precisely how does the hormone do this? In a paper published in April, research revealed oxytocin stimulates key neural circuits that permanently alter behavior in lab mice.

When baby mice fall out of their nests, their distress calls prompt their moms to retrieve them. Virgin females, however, are utterly indifferent to these cries — until they're given a surge of oxytocin.

The hormone works by binding to brain cell receptors. A New York University team looked at the effects of oxytocin three different ways. They injected it into the mouse's bloodstream or infused it onto the area of the brain that processes sound. They also stimulated the brain to release more of the hormone on its own. In each scenario, virgin females transformed into nurturing moms in response to pup calls. Oxytocin seems to amplify social information processed in the brain, turning an otherwise irrelevant sound into one that stands out.

"Adding oxytocin made permanent behavioral changes," says study lead author Bianca Marlin of NYU. "Mice that didn't know how to perform a social task could suddenly do it perfectly." —LINDA MARSA

LEFT: MARTA FLORIO AND WIELAND B. HUTTNER/MAX PLANCK INSTITUTE OF MOLECULAR CELL BIOLOGY AND GENETICS. RIGHT: LORADO/ISTOCK

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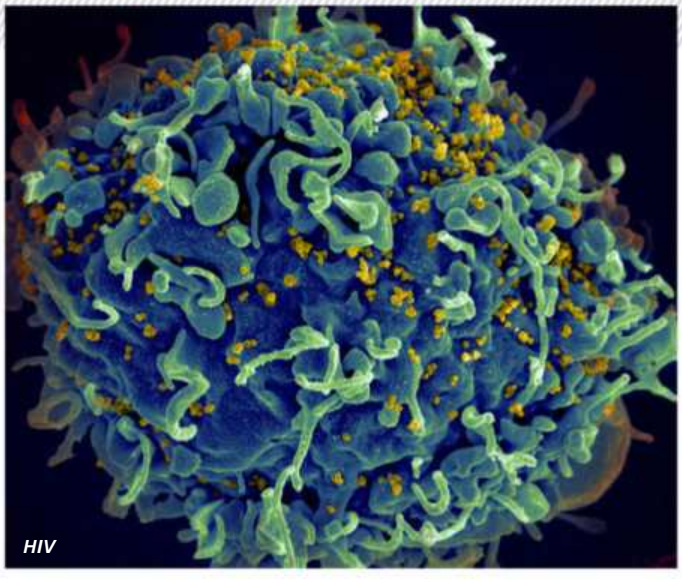
68

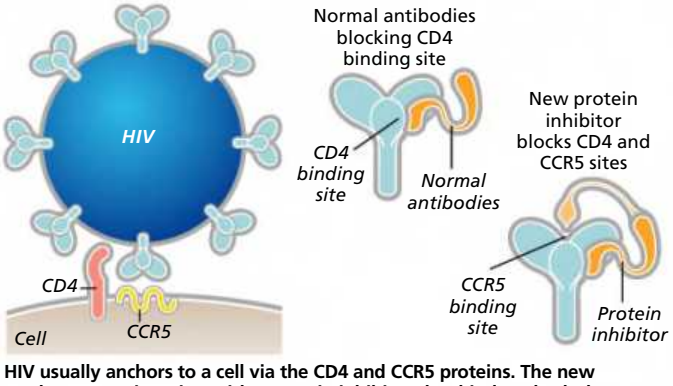
Technique Blocks HIV Invasion

For decades, researchers have been trying — unsuccessfully — to develop a vaccine that spurs the body to attack HIV. But immunologist Michael Farzan of the Scripps Research Institute in Florida published a *Nature* paper in March that described a way to neutralize the virus itself.

Farzan and his team discovered in their work with monkeys that HIV can't invade cells if those cells' two surface receptors are blocked — like a keyhole jammed with gum. Past approaches that tried to neutralize HIV used antibodies that blocked only one receptor at a time. But Farzan and colleagues created a protein inhibitor that mimics an antibody and can block both receptors at the same time. To slip in now, the virus must evolve in ways that will make it less dangerous, Farzan says.

Rhesus macaques that received the inhibitor were protected against infection from the monkey equivalent of HIV and fought off viral doses higher than any existing vaccine could touch, Farzan says. It now needs further testing in infected monkeys before advancing to human trials. —KAREN WEINTRAUB



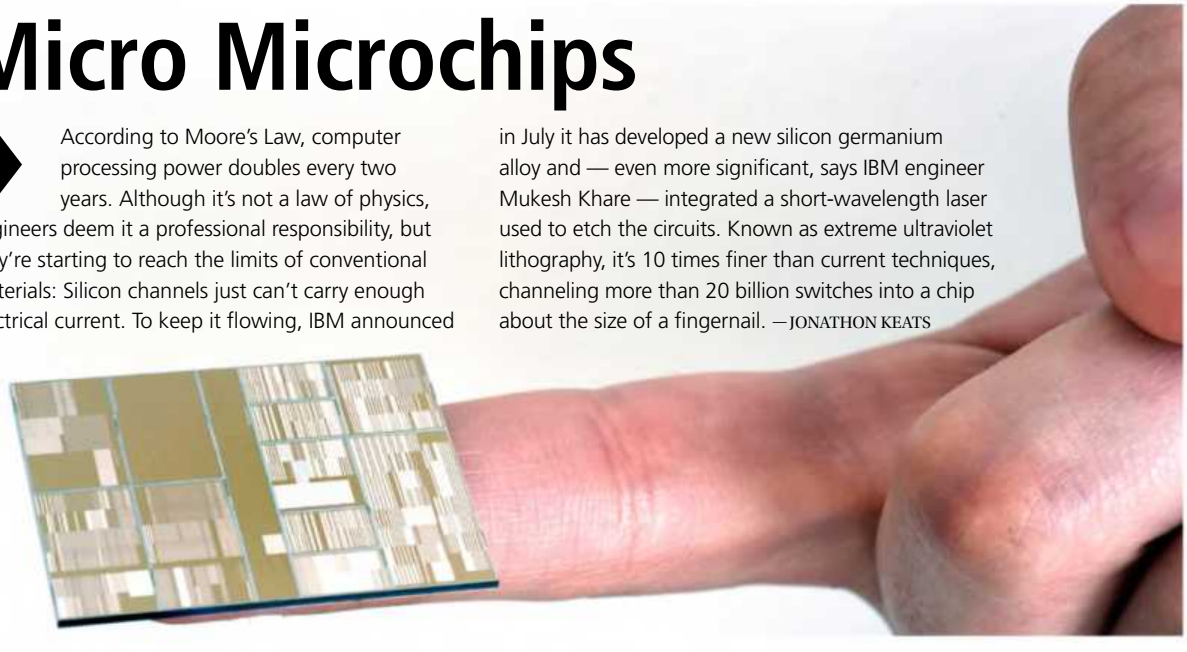


HIV usually anchors to a cell via the CD4 and CCR5 proteins. The new work prevents invasion with a protein inhibitor that binds to both the CD4 and CCR5 sites on the virus.

69

Micro Microchips

According to Moore's Law, computer processing power doubles every two years. Although it's not a law of physics, engineers deem it a professional responsibility, but they're starting to reach the limits of conventional materials: Silicon channels just can't carry enough electrical current. To keep it flowing, IBM announced in July it has developed a new silicon germanium alloy and — even more significant, says IBM engineer Mukesh Khare — integrated a short-wavelength laser used to etch the circuits. Known as extreme ultraviolet lithography, it's 10 times finer than current techniques, channeling more than 20 billion switches into a chip about the size of a fingernail. —JONATHON KEATS



FROM TOP: COURTESY OF ROCKY MOUNTAIN LABORATORIES/NIAID/NIH HAMILTON, MT; JAY SMITH; DARRYL BAUTISTA/FEATURE PHOTO SERVICE FOR IBM

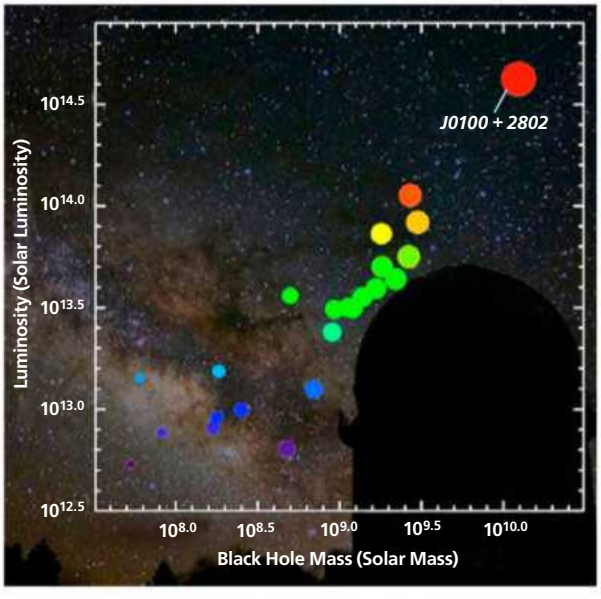
Ferocious Black Hole Found

Sometimes black holes just don't follow the rules. Astronomers announced in February that they found a black hole much bigger than it has any right to be — 12 billion times our sun's mass, a shocking weight considering its age. The finding challenges theories of how black holes form.

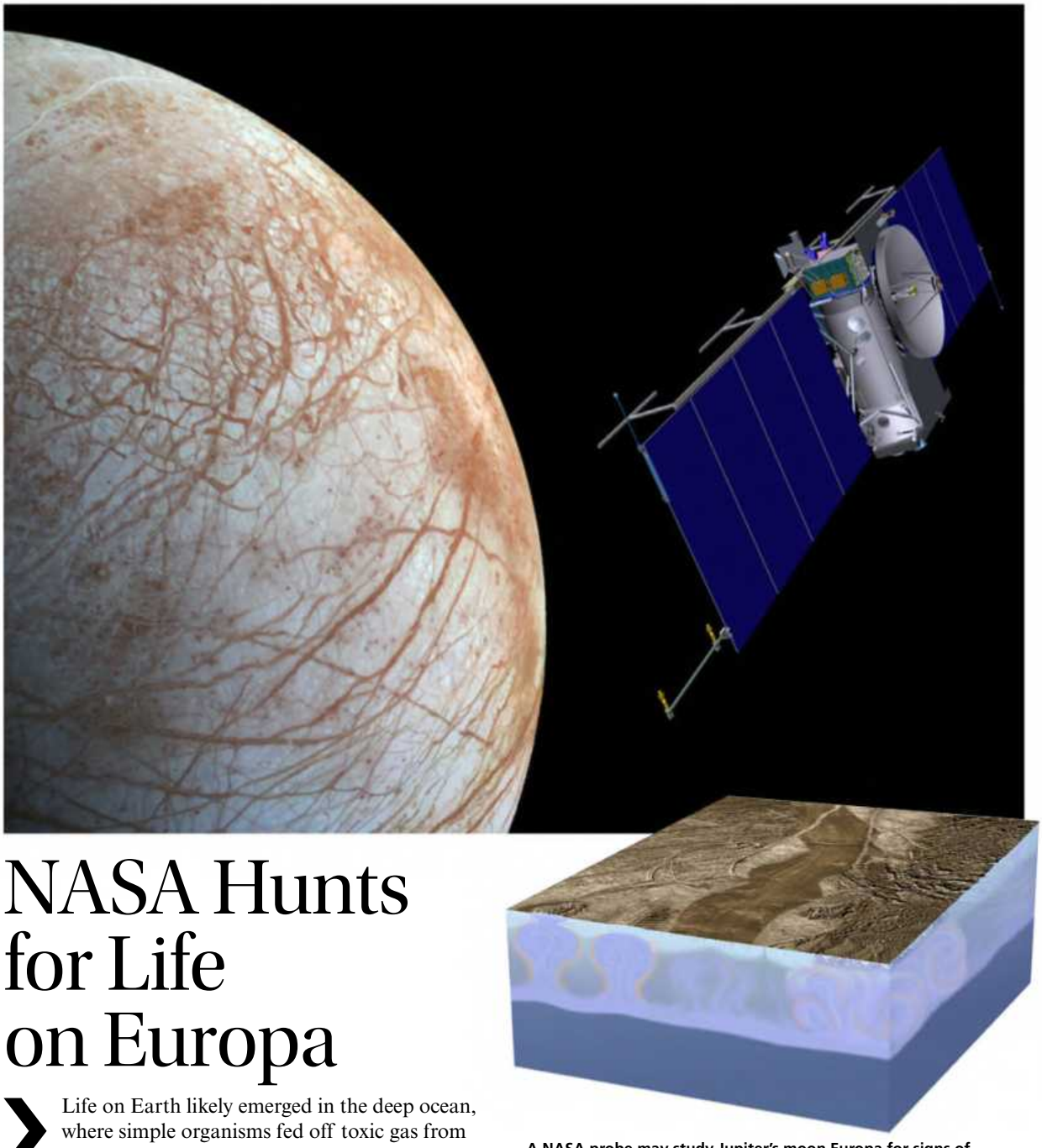
When Xue-Bing Wu of Beijing's Peking University and colleagues wanted to find the universe's oldest black holes, they looked for bright old galaxies, since most large galaxies have a central supermassive black hole. When a black hole pulls in nearby stars and gas clumps, the material circles the dark object, like water around a drain. Friction in this disk heats the material, which then glows.

Wu's team searched archived images of the sky for bright light sources, and after finding a promising one, called J0100+2802, they focused on it with five telescopes. Once Wu's team confirmed that the black hole was indeed ancient — formed just 900 million years after the birth of the universe — they discovered its outsized weight by analyzing its light.

This supersized black hole is about 10 times heavier and brighter than others discovered from the same time period, says Wu, suggesting it grew extremely rapidly. Theorists are now trying to figure out how. —LIZ KRUESI



TOP: ZHAOYU LI/NASA/JPL-CALTECH/MISTI MOUNTAIN OBSERVATORY. BOTTOM: ZHAOYU LI/YUNNAN OBSERVATORY



NASA Hunts for Life on Europa

Life on Earth likely emerged in the deep ocean, where simple organisms fed off toxic gas from volcanic vents. Earth's oldest ecosystems have inspired NASA to send a probe to search for signs of life in even harsher climes: Jupiter's ocean moon Europa. After NASA selected the mission's instruments in May, it officially moved the probe into development in June, setting the stage for a possible 2022 launch.

Scientists have long suspected a process similar to that around Earth's volcanic vents takes place beneath Europa's fragile icy shell, making the moon one of the most promising locations to find extraterrestrial life.

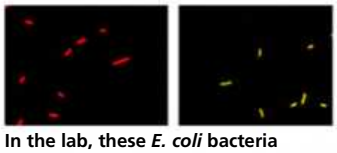
A NASA probe may study Jupiter's moon Europa for signs of life within a decade (top). A cross section of the moon's surface (above) shows its layer of icy crust above a liquid water ocean.

Depending on the probe's final configuration and launch date, it could reach Europa as early as 2026. With 45 close approaches — including some just 15 miles from Europa's surface — the probe will finally provide some answers, studying the moon's interior and taking pictures as good as the best close-ups of Mars from orbit. —ERIC BETZ

NASA/JPL-CALTECH (2)

72

Engineered Safeguard Keeps GMOs in Check



In the lab, these *E. coli* bacteria (left), engineered to rely on a synthetic amino acid, began dying (right) when deprived of it.

Genetically modified organisms show promise for everything from making vaccines to cleaning up oil spills. But that promise has been clouded by concerns over their potential to escape into the wild and harm ecosystems. Now, scientists have found a way to keep GMOs from going rogue.

In January, researchers at Harvard and Yale reported they had reprogrammed the genome of *E. coli* bacteria so the cells are dependent upon an amino acid that doesn't exist in nature. After growing 1 trillion bacterial cells and then depriving them of the synthetic amino acid, not a single one survived, suggesting they'd quickly perish in the wild.

In previous efforts to contain GMOs, organisms found a backdoor escape route by evolving out of their engineered weakness or scavenging nutrients from their environment. This new technique greatly reduces those risks.

"Biotechnology is going to play an important role in society, economy, medicine and health," says Farren Isaacs, lead researcher of the Yale study. "It's really important to introduce these safeguards from the onset."

—ANDY BERGER

FROM LEFT: JAYMIN PATEL/SYSTEMS BIOLOGY INSTITUTE/YALE UNIVERSITY; LAURENT MEKUL; SERGIO BERTAZZO/IMPERIAL COLLEGE LONDON

73

Dinosaur Soft Tissue Found in the Strangest Place

An off-the-clock project begun on a whim may cause paleontologists and museum curators to rethink their fossil collections.

Preserved soft tissue from dinosaurs is limited to a handful of exceptional specimens. In all but the most unusual circumstances, the tissue breaks down quickly after death — even remnant proteins were believed to last a few million years at most.

In June, however, researchers reported evidence of blood cells and collagen fibers in poor-quality fossil fragments that were 75 million years old. The discovery opens a new avenue into studying dinosaur physiology and could spur changes in how fossils are analyzed.

The project was born when paleontologist Susannah Maidment and biomedical researcher Sergio Bertazzo struck up a casual conversation at Britain's Imperial College London. Bertazzo, who researches microcalcification in living tissue, was curious to see what fossils looked like under a scanning electron microscope. Maidment, who studies dinosaur motion, was intrigued, too.

"The museum was worried we would destroy whatever they gave us, so they gave us 'bad' samples that were just sitting there for more than 100 years," says Bertazzo.

Bertazzo was shocked when he saw what appeared to be blood cells in the fossils. Maidment was skeptical: "I thought it had to be bacteria, or pollen, or modern contamination."

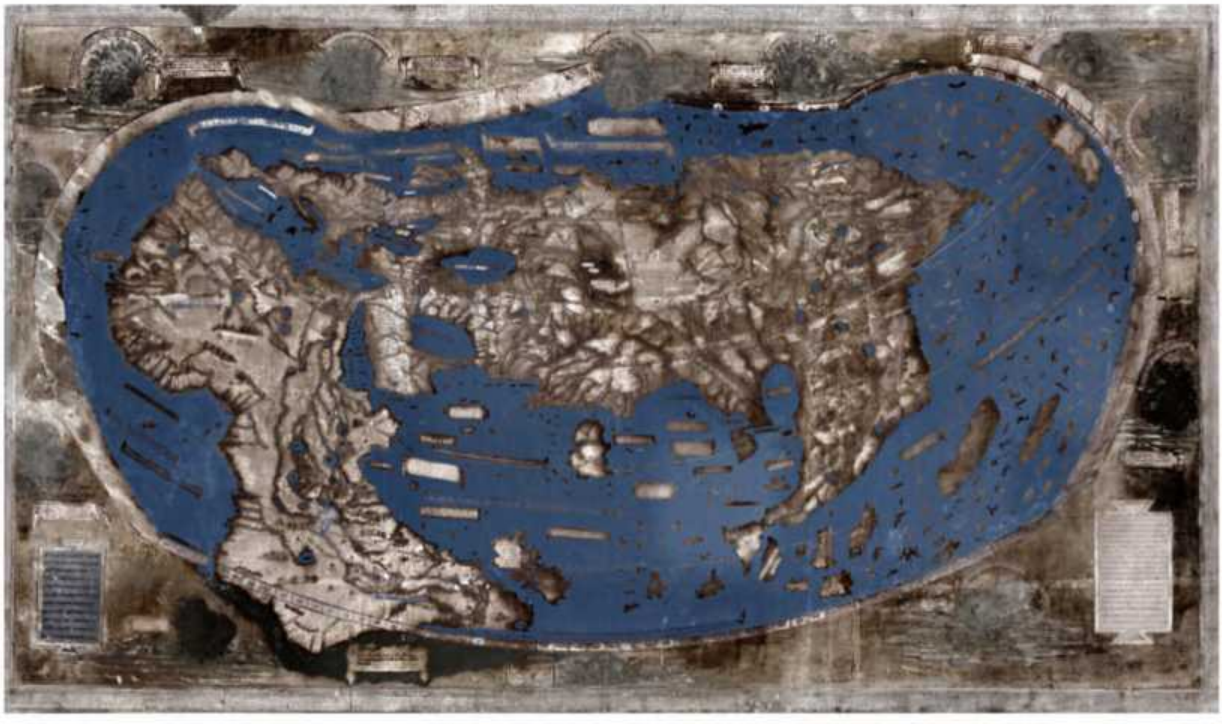
But additional research has confirmed that structures resembling blood cells and collagen protein fibers — key elements of connective tissue — were preserved in six of eight fragments. The findings mean that even subpar fossils discarded at digs or tossed in museum collection junk drawers could yield valuable evidence about how dinosaurs lived and evolved.

—GEMMA TARLACH

Among the fossils studied was this claw of an unidentified theropod, found in Canada in the early 20th century. Inset: After analyzing the claw, researchers found structures resembling blood cells, shown in red.

74

Shedding Light on Ancient Maps



Because of its faded condition, a map of the world (above) drawn by Henricus Martellus in about 1491 has stymied researchers for decades. Multispectral imaging at last revealed descriptions of regions and peoples (top).

The 1491 Martellus map has long been hailed as one of the most detailed and influential depictions of the known world at that time, yet the writing on the historical gem had faded over the centuries and was largely undecipherable.

That changed when researchers announced in June that they had used a multispectral imaging technique to analyze the 4-by-6½-foot map, which likely influenced Christopher Columbus' understanding of world geography. The team divided the large map into 55 overlapping tiles and imaged each one with 12 different light frequencies, ranging from ultraviolet to infrared. Each frequency revealed slightly different details, and for the first time, historians could see Henricus Martellus' descriptions of regions and peoples. They also confirmed that his text had been borrowed in 1507 by another well-known German cartographer, Martin Waldseemüller.

Now plans are underway to use the imaging technique to decrypt other relics, including the Fra Mauro world map from 1455 and the earliest surviving globe from 1492, says Chet Van Duzer, the map historian who led the Martellus project. The technique is also illuminating ancient documents like the Dead Sea Scrolls and manuscripts known as palimpsests, in which the original writing was scraped off so the parchment could be reused. For scholars like Van Duzer, the technology is akin to wearing a pair of glasses that allow them to peer back in time — and the view of history keeps getting clearer.

—HEATHER STRINGER

LAZARUS PROJECT/MEGAVISION/RIT/EMEL/COURTESY OF THE BEINECKE LIBRARY/YALE UNIVERSITY (2)

Genome Reveals Clues to Octopus Intelligence

75

Octopuses hail from a humble neighborhood in the taxonomic tree: the mollusks, which include snails, clams and other dimwitted animals. Yet octopuses are clever critters, known to use tools in the wild, play in captivity and even watch what's happening outside their aquarium.

Scientists have long wondered how they evolved such smarts independently of mammals and birds. The sequencing of the octopus genome, published in August, offers a surprising answer.

The genome shows that octopuses have the same small repertoire of neurotransmission genes as lower mollusks. This limited set of nervous-system building blocks should have restricted their ability to develop advanced intelligence, says Daniel Rokhsar, an evolutionary biologist at the Okinawa Institute of Science and Technology Graduate University in Japan.

But Rokhsar and his collaborators found two vastly expanded gene families in octopuses: protocadherins, which steer neurons to connect into complex circuits during development, and C2H2 zinc finger transcription factors, which turn other genes on and off with exquisite precision. This could have enabled the genome to be expressed "in a more complicated way than in a clam or a snail," says Rokhsar. These two gene families likely allowed the octopus to build unique neural circuits serving functions such as memory, navigation and planning.

—DOUGLAS FOX

A Key Piece of the Pain Puzzle Is Solved

76

Most of us probably take for granted that physical pain — whether it be from a sports injury, a kidney stone or appendicitis — can be attributed to some form of inflammation and that it will end. Neuropathic pain, however, affords its sufferers no such luxuries. It's chronic and unrelenting, and its cause is unknown, making treatment difficult.

It turns out that neuropathic pain is triggered when the body experiences endoplasmic reticulum (ER) stress, a condition in which the production and transport of protein exceeds the cells' capacities, say researchers from the University of California, Davis. Because diabetics are at high risk of having neuropathic pain, the team studied diabetic rats that had neuropathic symptoms: hypersensitivity to touch and lack of heat sensation. And the rats' nerve cells showed clear signs of ER stress.

When the researchers treated the rats with a compound that blocks ER stress, the pain symptoms disappeared. Conversely, healthy rats developed neuropathy when they received chemicals that induce the stress response.

"Medications have historically focused on turning down the nerve response to pain, but now we've found one way to block the stress signal that generates the pain," says Bruce Hammock, corresponding author of the study, which was published in July.

While it usually takes years for a discovery to translate to new medication, there may be a shortcut in this case. A medication that blocks ER stress is already on the market to treat an entirely different condition called urea cycle disorder. It would take a horse pill of the current medication to quell neuropathic pain, Hammock says, but the compound has promise.

—HEATHER STRINGER

TOP: BRANDON COLE. BOTTOM: DIANE DIEDERICH/ISTOCK AND MILAGLI/SHUTTERSTOCK

77

NASA Tech Finds Buried Survivors

The April 25 earthquake in Nepal claimed more than 8,000 lives, but four men trapped under debris survived, thanks to the first field use of some NASA technology.

At the time of the quake, NASA happened to be working on a briefcase-size prototype of FINDER, a device that can detect a beating heart thumping beneath 30 feet of rubble. (FINDER stands for "Finding Individuals for Disaster and Emergency Response.") NASA sent two prototypes to Nepal to assist rescue workers scrambling to find people trapped beneath collapsed buildings.

FINDER sends out a microwave signal (which penetrates rubble), and software loaded onto a laptop pinpoints anomalies in the returning signal produced by tiny movements, such as the motion of a beating heart or a victim's breathing. The system filters out extraneous noise, identifies uniquely human movements and reveals a victim's location — the latest version to within 5 feet.

NASA uses the same microwave technology in satellites to measure, for example, sinking land due to changes in aquifer levels, or the motion of other planets' satellites. Jim Lux, FINDER project manager, says the device could also monitor patients' vital signs in trauma centers or ambulances — where every second counts — without needing to connect cumbersome electrodes. — CARL ENGELKING

Jim Lux (above) demonstrates the final prototype for FINDER, which was deployed to the field for the first time to help find survivors of the Nepal earthquake in April (top).

TOP: DAVID LEWIS, R4 INC. VIA NASA. BOTTOM: AUBREY GEMIGNANI/NASA

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P24640

78

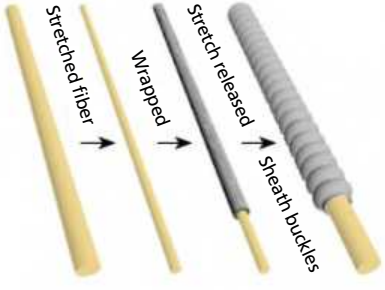
Stretchable Electronics Get Stretchier

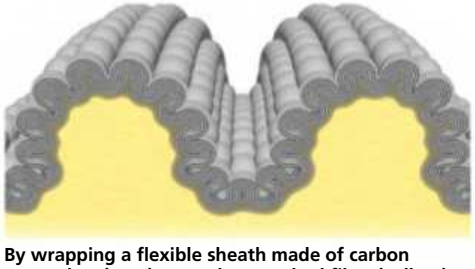
From health monitoring sensors woven into clothing to pacemaker leads that never wear out, stretchable electronics could usher in a new era of wearable tech. But finding superflexible alternatives to metal wires and semiconducting chips has been a challenge. In July, researchers unveiled a solution: elastic wires that can withstand both extreme strain and thousands of stretch-and-release cycles.

In previous attempts at making elastic conductors, researchers embedded conductive metallic particles into an elastic insulator, but stretching the material would cause breaks in the conducting path. These new wires can expand to 10 times their original length without choking off the current.

Materials scientist Ray Baughman and his team at the University of Texas at Dallas wrapped a sheet of conducting carbon nanotubes many times around a stretched rubber fiber, with the final product resembling a hair tie. When relaxed, the fiber core and nanotube sheath shrink together, causing the sheath to buckle like an accordion. The researchers found that as long as adjacent buckles don't touch, a current running through the sheath holds steady as the wire is stretched and relaxed.

Going a step further, the team added a rubber coating and a second nanotube sheath to the original wire to create an electrically activated "muscle" that contracts when connected to a battery. —ANDY BERGER

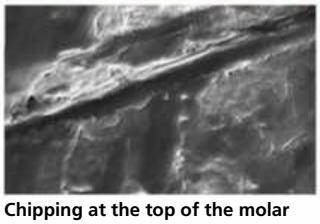




By wrapping a flexible sheath made of carbon nanotubes (gray) around a stretched fiber (yellow), scientists created an elastic conductor that could greatly improve stretchable electronics.

79

Open Wide and Say OUCH!



Chipping at the top of the molar shows an attempt to remove a cavity, while a microscopic view shows striations on the tooth.

Researchers have found evidence of the earliest known dental procedure, and it's not pretty. While examining the lower molar of a 14,000-year-old skeleton unearthed in northern Italy, University of Bologna archaeologist Stefano Benazzi discovered the tooth had a large cavity and numerous markings near it. Benazzi and his colleagues reported in *Scientific Reports* in July that the marks were made with a stone tool in an attempt to remove infected material from the cavity. The procedure "would have been quite painful," says Benazzi, who added it was only partly successful (though at least the patient survived). His analysis included replicating the damage on modern teeth — relax, he used teeth that were already extracted. The discovery means dentistry is at least 5,000 years older than previously thought. —GEMMA TARLACH

LEFT COLUMN: COURTESY UNIVERSITY OF TEXAS AT DALLAS ALAN G. MACDIARMID NANOTECH INSTITUTE (3). RIGHT COLUMN: STEFANO BENAZZI (2)

Treated Bats Become First Survivors of Deadly Disease

80

It must be a horrible way to die: A fuzzy, white mold penetrates the mouth and nose, leading to starvation and, finally, death. White nose syndrome (WNS), caused by a fungus, has killed as many as 6 million North American bats since winter 2006, sometimes wiping out whole colonies. But there's new hope for these denizens of the dark: In May, bats treated with a compound that inhibits the fungus's growth were released into the wild, becoming the first known WNS survivors.

After hibernating in refrigeratorlike chambers containing the compound, which is produced by a soil bacterium (a strain of *Rhodococcus rhodochrous*), diseased little brown and northern long-eared bats emerged healthy. On May 19, scientists released dozens of the bats near Mark Twain Cave in Missouri. Treated bats that remained in captivity fared well over the summer and fall. At the time of this writing, researchers were hopeful that the released bats would return to their winter hibernation sites in good condition.

"We're very excited," says Sybil Amelon, a research wildlife biologist with the U.S. Forest Service's Northern Research Station in Columbia, Mo. "We think it would be possible to treat enough locations effectively to increase the overall population." —APRIL REESE

White nose syndrome, caused by a fungus, infects the mouths and noses of several bat species, including little brown bats (top and above). The fungus makes the bats use more energy during hibernation and leads to death. Researchers treated a group of bats with a compound that inhibits the growth of the fungus and successfully released a healthy group (including the bat pictured at left) back into the wild this year.

FROM TOP: AL HICKS/NEW YORK DEPARTMENT OF ENVIRONMENTAL CONSERVATION; NANCY HEASLIP, NEW YORK DEPARTMENT OF ENVIRONMENTAL CONSERVATION; KATIE GILLIES/BAT CONSERVATION INTERNATIONAL

81

The *Ichibengops* skull has a distinctive groove along its jaw.

Groovy Fossil Find

Say hello to my extinct little friend: *Ichibengops* ("scarface") was a small carnivore that roamed the lowlands of today's Zambia about 255 million years ago. Researchers believe the lapdog-size animal may have been venomous because of a distinctive groove along the upper jaw, similar to a duct that transports venom from gland to tooth in some snakes.

But "Itchy" was no reptile: The animal, known from two partial skulls and described in July in the *Journal of Vertebrate Paleontology*, was actually an ancient mammal relative. "They look very different than mammals today," says team member and paleobiologist Kenneth Angielczyk of Chicago's Field Museum, "similar to the way a T. rex doesn't look much like a goldfinch." —GEMMA TARLACH

82

Giving Bees a Shot

The honeybee's immune system has a few tricks up its sleeve — tricks that scientists could soon tap to protect stressed bee populations.

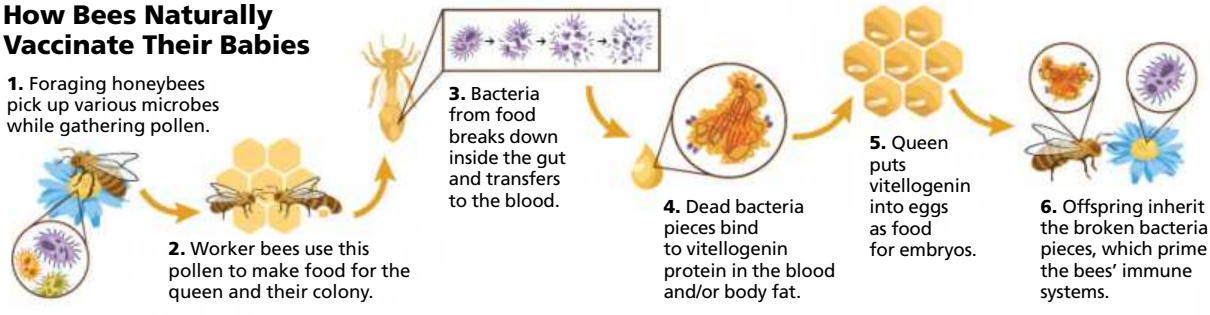
Insects don't produce antibodies, the immune system's way to remember and arm the body against recurring pathogens. Yet bees somehow pass along pathogen immunity to their young, something that shouldn't be possible without antibodies.

The missing mechanism lies within vitellogenin, a protein that transfers fat into egg yolk, says Gro Amdam, a biologist at Arizona State University. In research published in July in *PLOS Pathogens*, Amdam and colleagues in Finland show that this seemingly simple protein can bind to "pathogen patterns." These patterns are like molecular fingerprints for an invading microbe. Vitellogenin shares these patterns through the mother's hemolymph (the bee version of blood) with the developing embryo, sending along a "most wanted" poster for diseases the mother has already encountered.

Using this knowledge, researchers are developing an edible vaccine against American foulbrood, a disease that decimates honeybee hives. This could pave the way to develop more vaccinations to give stressed colonies an extra shot at life. —LEAH SHAFFER

Experts now know how bees inherit their immunity, a key to crafting vaccines for bees.

How Bees Naturally Vaccinate Their Babies

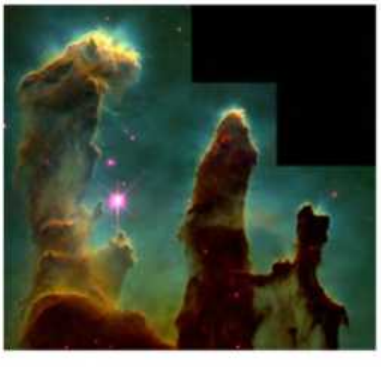


FROM TOP: ADAM HUTTENLOCKER/UNIVERSITY OF UTAH; CHRISTOFER BANG; SABINE DEVICHE/ARIZONA STATE UNIVERSITY. ADAPTED WITH PERMISSION

Hubble Revisits an Iconic Stellar Nursery

To celebrate Hubble's 25th anniversary, scientists captured a new look at a star-forming region seen in one of the space telescope's most iconic images. Using its latest camera, Hubble shows a wider and sharper view of the Eagle Nebula's "Pillars of Creation," immense columns of cold gas bathed in the ultraviolet light of nearby massive young stars. Such an environment likely reflects the same kind of setting in which our sun formed 4.5 billion years ago. — KARRI FERRON

The "Pillars of Creation" have changed subtly since the original photo (below).



TOP: NASA, ESA AND THE HUBBLE HERITAGE TEAM (STSCI/AURA). BOTTOM: NASA, ESA, STSCI AND J. HESTER AND P. SCOWEN (ARIZONA STATE UNIVERSITY)

84

No, Tropical Deforestation Rates Aren't Falling

Rainforests have been called "the lungs of the planet." They breathe out life-giving oxygen and absorb carbon dioxide, limiting global warming. A study published in May suggests these forests are more at risk than ever, contradicting earlier reports of a slowdown in deforestation.

Analyzing more than 5,000 high-resolution satellite images from the 1990s and 2000s, geographers at the University of Maryland discovered that rainforest loss accelerated by 62 percent during those two decades. "If this trend continues," lead author Do-Hyung Kim warns, "the vast tropical forests of today may soon be a relic of the past."

A 2010 United Nations report said deforestation rates were decreasing, but it turns out that analysis was based in part on unreliable government data. Even in Brazil, which succeeded in slowing deforestation for a decade, forest loss is again on the rise. For example, a monthly analysis of satellite images by the Brazilian nonprofit Imazon shows that in April 2015, more than twice as much forest had been cleared compared with the same month the previous year.

Forest experts blame the uptick in deforestation on a weakening of forest protections, leading to increased clearing for agriculture and new roads and dams.

Deforestation isn't confined to the tropics. In September, scientists examining global tree cover discovered that while there are 3 trillion trees on Earth — more than seven times as many as scientists thought — the planet has lost 46 percent of its forests since the onset of agriculture about 12,000 years ago. The report estimated that 15 billion trees are felled each year. The Yale University-led analysis, which combined on-the-ground surveys with satellite data, shows "the overwhelming effect of humans across most of the world," the authors wrote. —RICHARD SCHIFFMAN

Rain-forest loss accelerated by **62%** during the 1990s and 2000s

Deforestation has transformed landscapes throughout the world, including this area of the Amazon near the Brazilian village of Buritis. These satellite images, encompassing an area about 150 miles wide, show a tremendous loss of forest over just 12 years.

The planet has lost **46%** of its forests in the past 12,000 years

15 billion trees are felled each year

An area near Acre, Brazil, shows the progression of forest to grazing land on a large cattle ranch: intact forest (left), forest being burned to make pasture (top), newly cleared forest (bottom) and grass ready to graze (right). Recent studies show an uptick in deforestation.

TOP: NASA/EARTH OBSERVATORY (2). BOTTOM: RICARDO FUNARI/BRAZIL PHOTOS/LIGHTROCKET VIA GETTY IMAGES

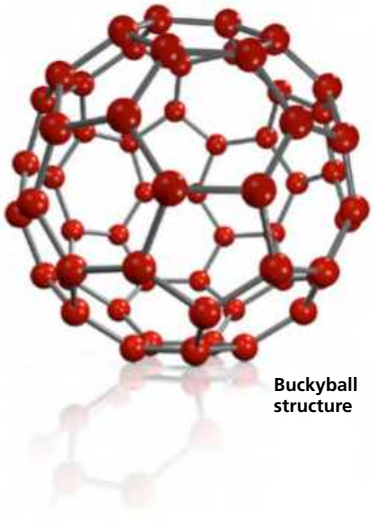
85

Organic Molecule Solves Space Mystery

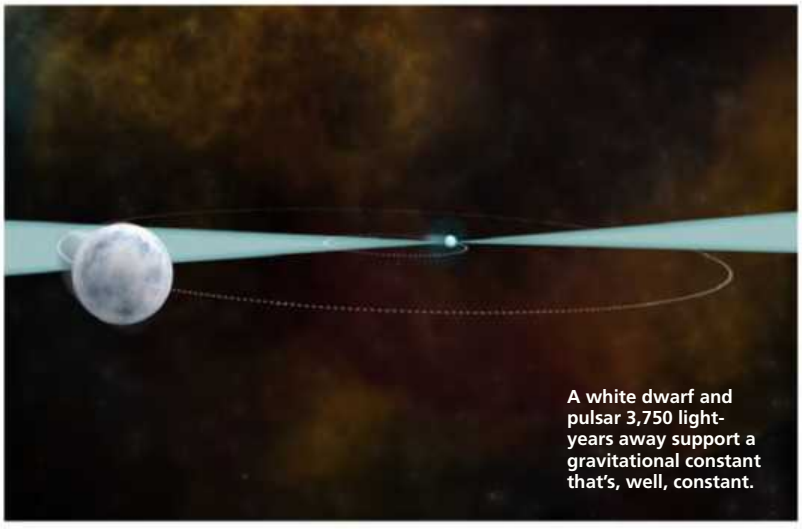
Buckyballs, carbon compounds shaped like soccer balls, can survive between stars and absorb their light, astronomers announced, helping solve a nearly century-old mystery.

In 1919, Mary Lea Heger, a graduate student at the University of California, Berkeley, saw that certain stars were missing some colors. Something between the star and Earth must be absorbing them, but what? In 1993, a team led by John Maier of the University of Basel in Switzerland found that buckyballs encased in a frozen solid absorbed the right colors. But did they behave the same way in interstellar space?

In July, Maier and his team proved it. They chilled buckyballs to nearly absolute zero and put them in a vacuum, mimicking the conditions of the cosmos. The balls absorbed the same colors missing in space. Mystery solved. —SARAH SCOLES



Buckyball structure



A white dwarf and pulsar 3,750 light-years away support a gravitational constant that's, well, constant.

86

Testing Gravity's Reach

While your own weight may fluctuate, the fundamental constant of gravity, which keeps your feet on the ground and the Earth going around the sun, is the same everywhere at all times. Or so Einstein's theory of gravitation claims, at least. Alternative theories have speculated that this constant might in fact vary as the universe expands, or near objects of drastically different densities, fundamentally changing our understanding of how the cosmos operates.

The Arecibo Observatory (above) and Green Bank Telescope helped astronomers study gravity's strength in the universe.

Astronomers tested for changes in the gravitational constant using 21 years of data from a pulsar (the ultradense remnant core of a dead star that spins like a crazed lighthouse, sending astronomers bursts of light a thousand times per second). PSR J1713+0747, as it is known, has a tiny white dwarf companion star, and the two orbit each other exceptionally predictably. By accounting for every factor that perturbed their dance over 21 years, astronomers ruled out any change in the underlying gravitational constant.

Astronomers have used laser ranging studies, bouncing light beams between Earth and the moon, to prove gravity's constancy locally for decades. And if gravity is changing, a dramatic and faraway pulsar system should show the effects most clearly. Combined with the local lunar data, the new research, published in August, is the best proof yet that gravity is truly constant no matter where in the universe scientists look. —KOREY HAYNES

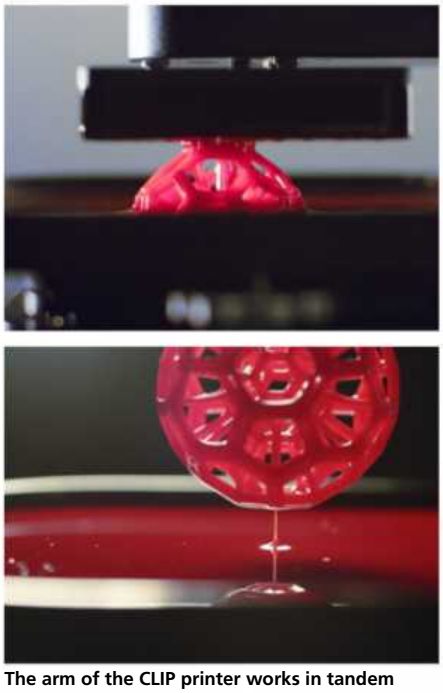
FROM TOP: B. SAXTON (NRAO/AUI/NSF); COURTESY OF THE NAIC-ARECIBO OBSERVATORY, A FACILITY OF THE NSF; MAGGIO07/ISTOCK

87

Liquid 3-D Printer Is Speedy

A new 3-D printer makes objects appear to grow from primordial goo, all in a matter of minutes.

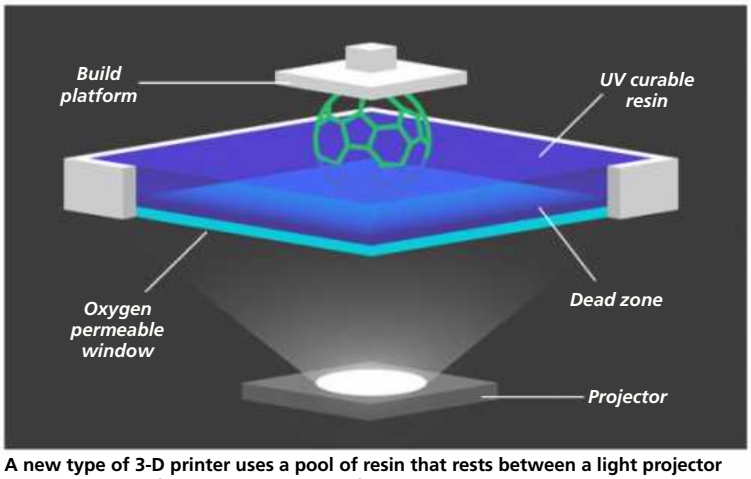
The Continuous Liquid Interface Production technology (CLIP), reported in March in *Science*, features a pool of specialized resin that hardens when exposed to light but remains liquefied when exposed to oxygen. A projection system flashes ultraviolet light patterns through an oxygen-permeable window beneath the resin while a mechanical arm pulls the object upward as it's being created. Since the light and arm work in tandem, shapes and lattices can be printed continuously rather than layer by layer, like — dare we say — "old-fashioned" 3-D printers.



The arm of the CLIP printer works in tandem with a light projection system. The resin hardens in just minutes as it's exposed to light.

The CLIP is fast: An intricate, 51-millimeter structure emerges from the resin in six and a half minutes. The same job with a traditional 3-D printer would take three hours. — CARL ENGELKING

Continuous Liquid Interface Production



A new type of 3-D printer uses a pool of resin that rests between a light projector and building platform. The resin is liquefied — the dead zone — as long as it's in contact with oxygen. It will harden in light, appearing to rise from the pool.

88

Big Fine for Fraud

In July, an Iowa District Court sentenced biomedical researcher Dong-Pyou Han, formerly of Iowa State University, to 57 months in prison and $7.2 million in restitution for scientific misconduct. The unusual sentence sparked debate among scientists on whether the punishments fit the crime.

Han altered rabbit blood samples to artificially boost HIV vaccine test results, leading to millions in grant money. A 2013 investigation by the U.S. Office of Research Integrity uncovered his misdeeds. The agency imposed a three-year research ban on Iowa State, which returned $500,000 in grant money. Criminal charges followed in June 2014 after the case gained widespread attention.

Extreme fraud like Han's is rare, but subsequent legal prosecution is almost unheard of, says Daniele Fanelli, a meta-researcher at Stanford University. Fanelli believes similar prosecutions may follow. "This might have serious consequences on scientific progress," he says, both positive and negative. "If you turn a judgment about scientific truthfulness into a legalistic manner, then scientists may get away with fraud thanks to having a good lawyer." — STEPHEN ORNES

Dong-Pyou Han's tampering with HIV vaccine tests led to him facing serious criminal charges, including prison time.

LEFT COLUMN: COURTESY CARBON3D (3); RIGHT COLUMN: CHARLIE NEIBERGALL/AP/CORBIS

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Before his death, Cecil the lion was the leader of his pride.

Cecil's Conservation Legacy

Q&A

On July 4, the signal from Cecil the lion's satellite collar went dark. Oxford University's WildCRU (Wildlife Conservation Research Unit) had been following his every move for eight years as part of a study of his pride. As rumors of a dead lion near Zimbabwe's Hwange National Park spread, WildCRU founder David Macdonald and colleague Andrew Loveridge feared the 13-year-old patriarch had been killed.

They were right. American dentist Walter Palmer, aided by hunting guides, had fatally wounded Cecil. His death went viral, spurring international outrage — and new support for lion conservation. As of October, WildCRU had received more than $1 million, thanks in part to talk show host Jimmy Kimmel's solicitation of donations in Cecil's memory. *Discover* spoke with Macdonald about the impact Cecil's death has had on WildCRU's work.

—KRISTIN OHLSON

***Discover*: How has Cecil's death affected your study?**

David Macdonald: It's important for us to understand how lion societies react to mortality of all sorts within the population. At a scientific level, Cecil's death — to put it coldly — is another data point for us in studying the consequences of adult male pride lions dying, which can include social turbulence and infanticide.

A less scientific answer has to do with the attention and donations Cecil's death has brought to a project that operates hand-to-mouth. Millions of people are sending a signal that they value lions and big carnivores and wildlife. It's a historic moment, one we must grasp to ensure that conservation does not simply go on with business as usual.

Biologists David Macdonald (left) and Andrew Loveridge examine a sedated lion in Zimbabwe's Hwange National Park.

How will you spend the money?

Most of these donors have given money because of their interest in lion conservation in the landscape occupied by Cecil and other members of his population: Zimbabwe

FROM TOP: CHRISTOPHER SCOTT/ALAMY; WILDLIFE CONSERVATION RESEARCH UNIT

Protesters in Bloomington, Minn., demonstrate in front of Walter Palmer's offices in July. Three months later, Zimbabwe officials declined to charge the dentist and hunter (right, arriving at his office), saying he broke no laws.

and the adjoining countries, particularly Botswana, Namibia and Zambia. It had always been our plan to expand the work beyond the park to these adjoining lands. We are also growing the project in its existing areas and will expand our intensive biological study of the lions so that our policy and conservation advice can be more evidence-based. In addition, we will be training a lot of marvelous young Zimbabwean conservationists.

You've studied lions for nearly 20 years. How has your research informed conservation efforts? What has changed?

A huge amount has changed. We work on all aspects of lion conservation in this landscape, including illegal poaching, illegal and legal trophy hunting, land use change around the park, and conflict between people in local communities and the lions. We have delivered astonishing practical results. For instance, we have trained local people to act as guards — we call them "long shields" because in their culture, the shield is important protection — to keep the lions away from livestock. When our satellite-tracked lions leave the park and enter farmland, which they do regularly and naturally, the satellite transmitters tell us where the lion is going. We contact one of our local guards, whom we have provided with mountain bikes, GPS and cell phones, and give him the lion's location. He cycles off to the farming community and helps people lock up their livestock, then uses the vuvuzela — a trumpetlike instrument that fans use at football matches in southern Africa — to drive the lion back into the park. We've cut the loss of livestock by 50 percent. So our results are both scientifically cutting-edge and highly successful in helping the local communities.

FROM LEFT: GLEN STUBBE/ZUMA PRESS/CORBIS; ADAM BETTCHER/GETTY IMAGES; PHOTO QUEST LTD/CORBIS; CHAD SPRINGER/CORBIS

90

Sweet, Sweet Pain Relief

Hospital patients might someday fight pain with opioids manufactured from sugar-gobbling yeast similar to what brewmasters and bakers use.

In August, Stanford synthetic biologist Christina Smolke and her team announced successfully using genetically modified baker's yeast, one strain to convert glucose into the opioid hydrocodone and another strain to create thebaine, an opioid precursor. Other research groups completed the 15-step conversion this year using several yeast strains together, but Smolke's team was the first to use just a single strain to pull off the conversion from start to finish.

To get the more than 20 enzymes needed to complete the conversion from glucose to painkillers, the team spliced genes from plants, bacteria and even rats into yeast.

The new process could yield more effective, less addictive and cheaper drugs, but also raised concerns that hobbyists could someday home-brew opioids. To test that theory, Smolke's team tried — and failed — to create opioids with an over-the-counter brew kit.

"When you home-brew, you grow yeast populations very differently than in a lab or for commercial production," she says.

For the new technique to be commercially viable, the engineered yeast needs to perform the conversion more efficiently and optimize fermentation, Smolke says. —CARL ENGELKING

Experts created opioids from a yeast strain similar to baker's yeast (above) or brewer's yeast (right).

91

Behold the Eternal Camera

This camera is its own power source.

Light is energy. Cameras need energy to work. A modern camera works by sensing light. This cycle has provided an elegant solution to one of our digital age's universal problems: how to power a camera infinitely.

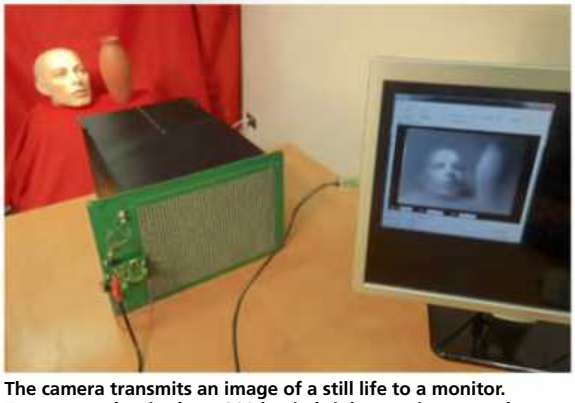
Digital cameras create images based on data from millions of photodiodes, each of which measures the amount of light it receives. But solar panels use photodiodes, too, converting light energy into electrical energy.

In April, a Columbia University team unveiled the first working prototype of an "eternal camera," which records video and provides its own power, even in indoor settings. The team developed a design that continually toggles between measuring and harvesting light.

The possibilities could be as limitless as the camera's power supply, from wildlife monitoring to law enforcement.

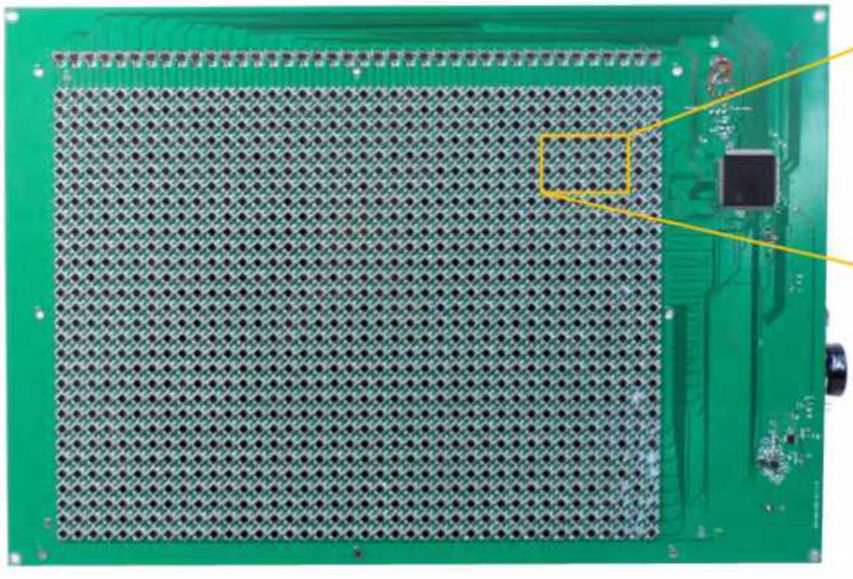
"We're really in the middle of an imaging revolution, but if you want to see images becoming ubiquitous — I'm not talking about pretty pictures, but as a way to document life — you don't want these devices tethered [to a separate power source]," says computer science professor and project leader Shree Nayar.

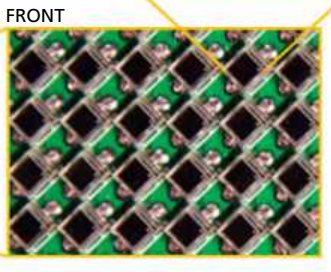
Nayar's team will spend the next year or so shrinking the "big, clunky device," boosting its power and enabling it to communicate wirelessly. — GEMMA TARLACH

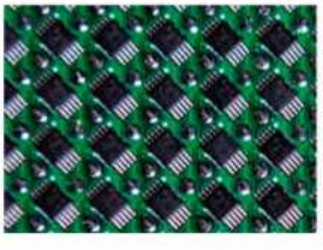


The camera transmits an image of a still life to a monitor. For a scene that is about 300 lux in brightness, it can produce an image per second, indefinitely.

The front of the board has a 30x40 grid of photodiodes. The array on the back of the board allows the camera to switch between recording an image and harvesting energy to charge the camera.







ALL IMAGES: COMPUTER VISION LABORATORY/COLUMBIA ENGINEERING

92

Efficient Stem Cells Can Grow in Animals

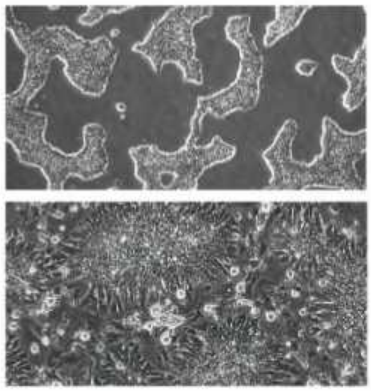
Working with stem cells comes at a price. When isolated, 99 percent of stem cells die, making it prohibitively difficult to manipulate their genes or expand their numbers for clinical use.

By tinkering with the medium in which cells are grown, researchers at the Salk Institute for Biological Studies created a type of stem cell with a survival rate of 30 to 40 percent, vs. 1 percent. The cells are far easier to culture, and their genetic defects are more readily repaired.

The human version of the cells, called region-selective pluripotent stem cells, or rsPSCs, can also grow inside a mouse, something other human stem cells can't do, says Jun Wu, a research associate involved in the work, published in May in *Nature*.

"It offers the first proof of concept that it's possible to incorporate human cells efficiently into another species," Wu says. This suggests someday it may be possible to grow a human organ, such as a pancreas, inside a pig and then transplant it into a diabetic patient.

—KAREN WEINTRAUB



The top and bottom photos show the difference in stem cell survival, merely by altering the medium used for growth.

CLOCKWISE FROM BOTTOM LEFT: COURTESY JUAN CARLOS IZPISUA BELMONTE/SALK INSTITUTE OF BIOLOGICAL STUDIES (2); DSDESIGN/SHUTTERSTOCK; SWIKED.TUMBLR.COM; ROMAN ORIGINALS VIA TWITTER

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More Than a Meme

Scientists all have go-to tools: Biologists have the lab mouse, while astronomers have the telescope. Now, color researchers have #TheDress.

Whether the frock looked white and gold or blue and black dominated the Internet for weeks in early 2015. But it was hardly idle chatter. Social media surfaced "a major scientific discovery for color vision," says Bevil Conway, a neuroscientist at Wellesley College in Massachusetts.

As Conway's group reported in one of a trio of papers published in June, about 60 percent of the 1,401 people they surveyed, both online and in the lab, saw blue and black, while 30 percent saw white and gold. (The other 10 percent saw blue and brown or a color combo defined as "other.") Nearly half who saw the image before the survey said their initial perception later flipped.

People see the viral image of the dress mainly two ways: sometimes blue and black, sometimes gold and white. It's actually blue and black (right).

There are many examples of color illusions, Conway says, but everyone seemingly experienced them in the same way. The dress is the first documented example of one image that causes at least two different color perceptions.

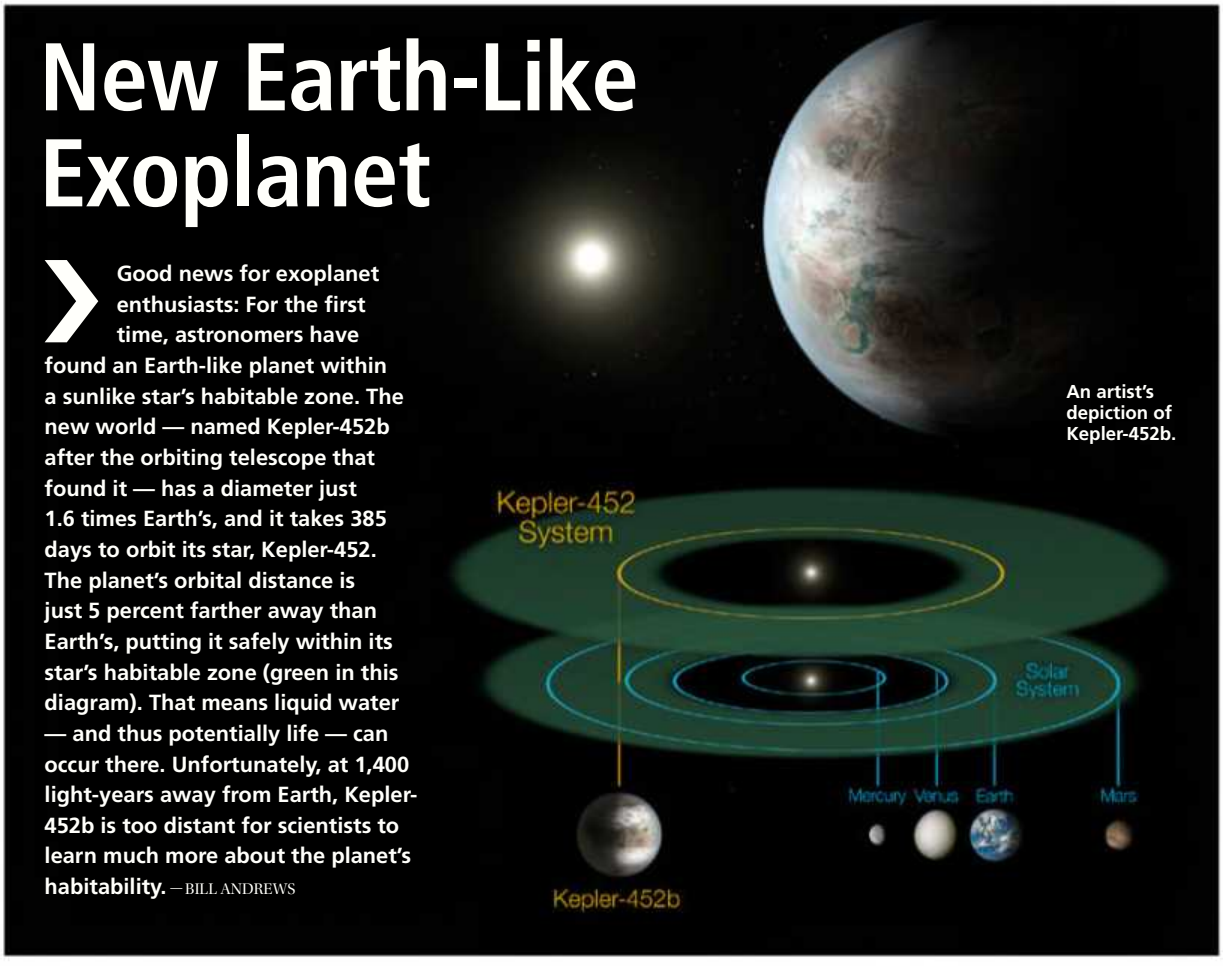
The ambiguity practically vanished when Conway added a body into the dress, indicating the image toys with our brain's color constancy system. That is, some viewers perceive the dress as lit with natural light and see white, while others perceive it as lit with incandescent indoor light and see blue. (It's actually blue and black.)

Dozens of labs are studying this photograph, Conway says, for insights into how and why people perceive color differently. So, though the Internet has moved on, #TheDress is here to stay. —LISA RAFFENSPERGER

94

New Earth-Like Exoplanet

Good news for exoplanet enthusiasts: For the first time, astronomers have found an Earth-like planet within a sunlike star's habitable zone. The new world — named Kepler-452b after the orbiting telescope that found it — has a diameter just 1.6 times Earth's, and it takes 385 days to orbit its star, Kepler-452. The planet's orbital distance is just 5 percent farther away than Earth's, putting it safely within its star's habitable zone (green in this diagram). That means liquid water — and thus potentially life — can occur there. Unfortunately, at 1,400 light-years away from Earth, Kepler-452b is too distant for scientists to learn much more about the planet's habitability. — BILL ANDREWS



An artist's depiction of Kepler-452b.

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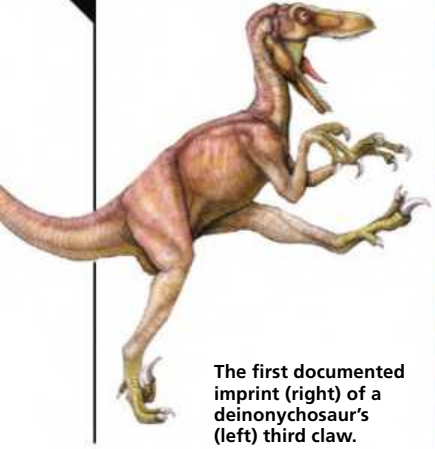
Capturing the Action of Raptor Traction



The first documented imprint (right) of a deinonychosaur's (left) third claw.

While hunky Chris Pratt was motorbiking through the *Jurassic World* jungle with his souped-up troupe of velociraptors, real paleontologists were analyzing unique fossilized tracks from a raptor that was on the loose more than 100 million years ago. Published in May in *Palaeoworld*, their report documents the first imprints of a raptor's third-toe claw.

Like velociraptors, the raptor that made the tracks came from a group of dinosaurs known as deinonychosaurs, which walked and ran on two toes. Deinonychosaurs typically kept the third toe of each foot raised and its claw retracted, like your average house cat, to protect the valuable weapon. "The ground would dull the claw," says University of Alberta paleontologist Scott Persons, part of the research team. "That's also why a cat's claws can rough you up, but a dog's, not so much."

Persons believes the unique three-toed raptor tracks, found with other dinosaur tracks in central China, may have been made when the coyote-size animal was moving through deep mud, using its claw for traction, like cleats on soccer shoes. — GEMMA TARLACH

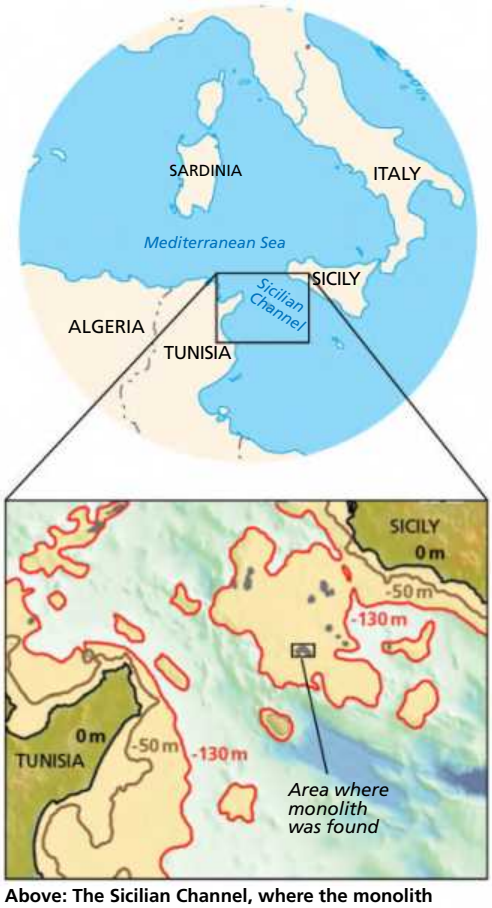
FROM TOP: NASA AMES/JPL-CALTECH/T. PYLE; NASA/JPL-CALTECH/R. HURT; ENCYCLOPEDIA BRITANNICA/UIG VIA GETTY IMAGES; LI-DA XING

What Lies Beneath

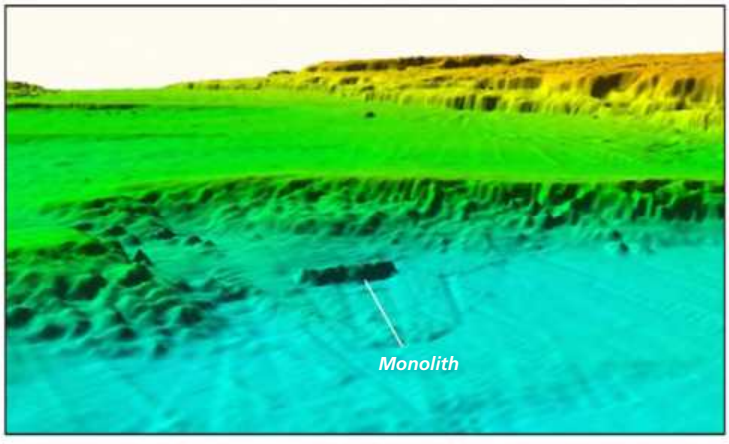
It's not the fabled Atlantis, but it is tantalizing: Researchers studying the Mediterranean's Sicilian Channel, an area now underwater but partially exposed as recently as 9,000 years ago, found a 40-foot-long monolith, broken in two, with uniform, regularly spaced holes that could not be explained through any natural process. Analysis confirmed the monolith was quarried from a rock formation about 1,000 feet from its resting place.

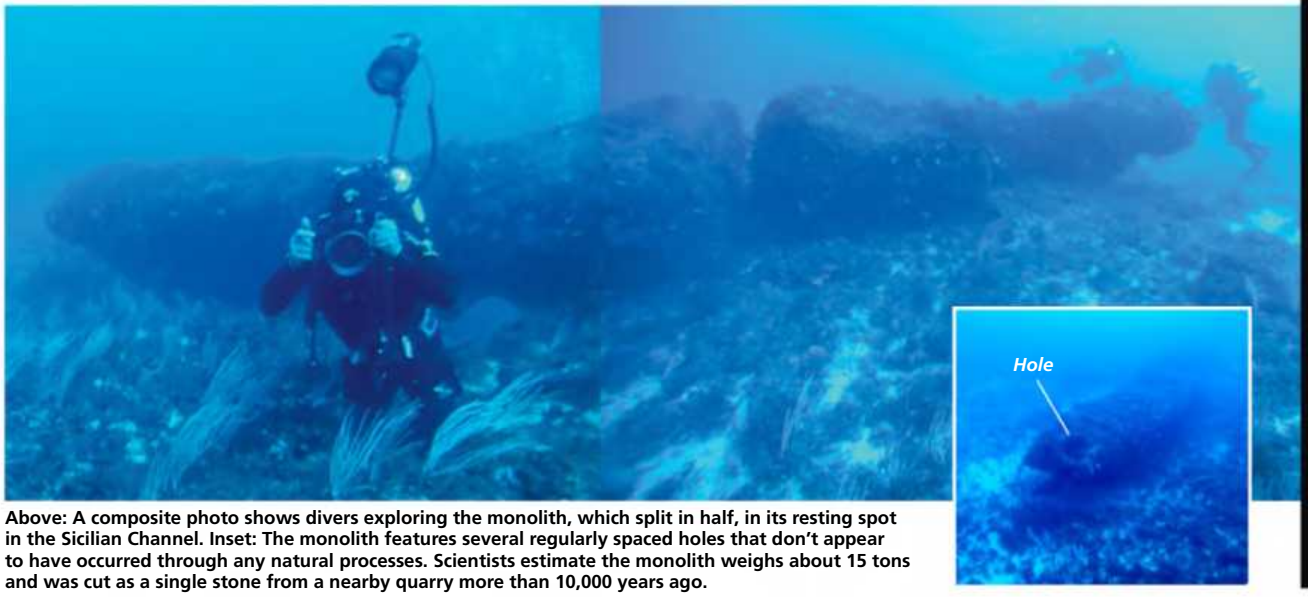
Still a mystery: Who created the monolith and other possibly man-made features nearby, including concentric circles and what may be a breakwater that's more than 250 feet long? "We have opened the door to the unknown," notes lead researcher Emanuele Lodolo, whose team published the find in the September issue of *Journal of Archaeological Science: Reports*.

—GEMMA TARLACH



Above: The Sicilian Channel, where the monolith was discovered, has experienced great variation in sea level. About 19,000 years ago, water levels were 130 meters lower than now (red line). When the monolith was quarried, levels were roughly 50 meters lower than today. Left: A 3-D view of the site.





Above: A composite photo shows divers exploring the monolith, which split in half, in its resting spot in the Sicilian Channel. Inset: The monolith features several regularly spaced holes that don't appear to have occurred through any natural processes. Scientists estimate the monolith weighs about 15 tons and was cut as a single stone from a nearby quarry more than 10,000 years ago.

FROM TOP: ALISON MACKEY/DISCOVER; EMANUELE LODOLO ET AL./JOURNAL OF ARCHAEOLOGICAL SCIENCE: REPORTS 3 (2015) 398–407 (4)

97

Pages From an Old Quran

For decades, two inscribed leaves of parchment sat in a research library at the University of Birmingham, England. Only by chance did a scholar notice them and suspect what they were: part of one of the first Qurans. By July, radiocarbon dating confirmed the parchment was made between A.D. 568 and 645. "The scribe may have heard the Prophet Muhammad speak, have seen him, or may even have known him [before his death in 632]," says David Thomas, professor of Christianity and Islam at Birmingham. The text is almost identical to that of the modern Quran, shedding light on Islam's earliest period and suggesting its most sacred book has changed little in 14 centuries. —GEMMA TARLACH

98

Neurons Alter DNA All Day, Every Day

The brain is quite the circus act: It constantly juggles the complex job of processing a daily barrage of new experiences with the equally daunting task of storing memories. But scientists never understood how it managed to pull this off. Now, two studies published in June reveal it's because neurons, brain cells that transmit messages, alter their DNA constantly.

The trick is methylation and demethylation — adding and removing chemical tags called methyl groups to specific locations on DNA that turn genes on and off without editing the genetic code itself.

Researchers recently discovered that adult mouse neurons methylate and demethylate — startling, since experts thought methylation happened only during brain development and then became permanent, to establish cells' identities. Given these findings, University of Alabama at Birmingham neurobiologist David Sweatt and Johns Hopkins University neurobiologist Hongjun Song wondered if methyl groups affected long-term memory formation.

The researchers knew that neurons fire at a steady rate to form memories but also that new experiences can overstimulate them. To mimic a learning experience and see how neurons keep their activity in check, each team tweaked rat or mouse neurons' firing rates, genetically or with drugs. To cope, the neurons used methylation and demethylation like a volume knob, constantly adjusting the signal strength of connected neurons by turning on or off the genes that make the signal receptors. This knowledge brings us one step closer to understanding memory at the molecular level. —ANDY BERGER

THE CADBURY RESEARCH LIBRARY/UNIVERSITY OF BIRMINGHAM

This 4-Legged Snake Was a Hugger

99

In 2011 British paleobiologist David Martill led his students on a field trip to a German museum to see the famed feathered dinosaur *Archaeopteryx*. But it was the 8-inch specimen labeled "unknown fossil" that caught his eye.

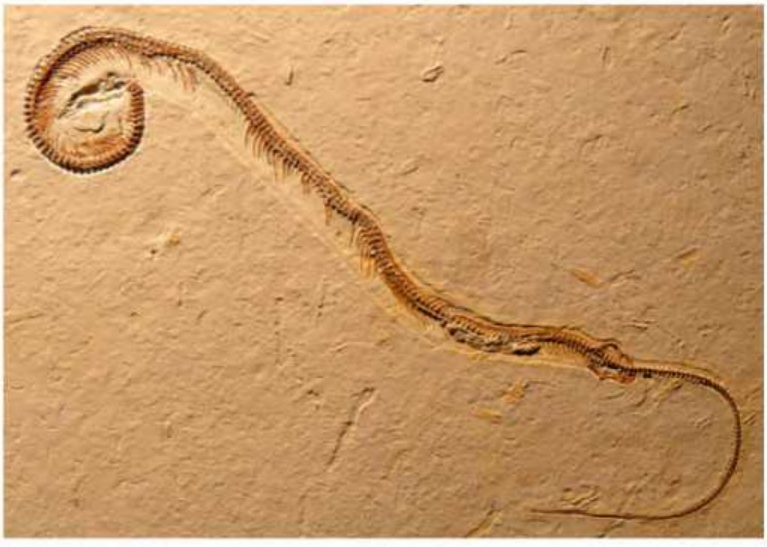
In a study published in July, he and a team identified four legs on the 272-vertebrate fossil, with hind legs nearly twice the size of the front legs. The scientists suspect that the legs were used for seizing prey or clasping during mating. "Our specimen suggests that snakes achieved many of their snakelike features before the legs disappeared," Martill says.

Some experts are not convinced it's a proto-snake, but Martill and his colleagues identified several features unique to snakes. Like snakes today, the teeth on the roughly 120-million-year-old *Tetrapodophis amplectus* — translated loosely as "four-legged hugging snake" — are welded to the jaw and directed backward, and there is a single row of belly scales.

The fossil also could shed light on the debate over whether snakes evolved from marine or terrestrial reptiles. The specimen's tiny claws and elongated phalanges would likely be used for burrowing, as opposed to paddling through water, says Martill.

— HEATHER STRINGER

An illustration shows the four-legged snake *Tetrapodophis amplectus* holding a mammal in a tropical forest in Gondwana, about 120 million years ago. The legs are thought to have been used during mating and for seizing prey.



The 8-inch fossil (left) of the 272-vertebrate *Tetrapodophis amplectus* features tiny claws and elongated hand bones (above) that researchers contend were likely used for burrowing. Some experts are not convinced that the fossil is a proto-snake.

TOP: JULIUS T. CSONYI. BOTTOM: DAVID MARTILL/UNIVERSITY OF PORTSMOUTH (2)

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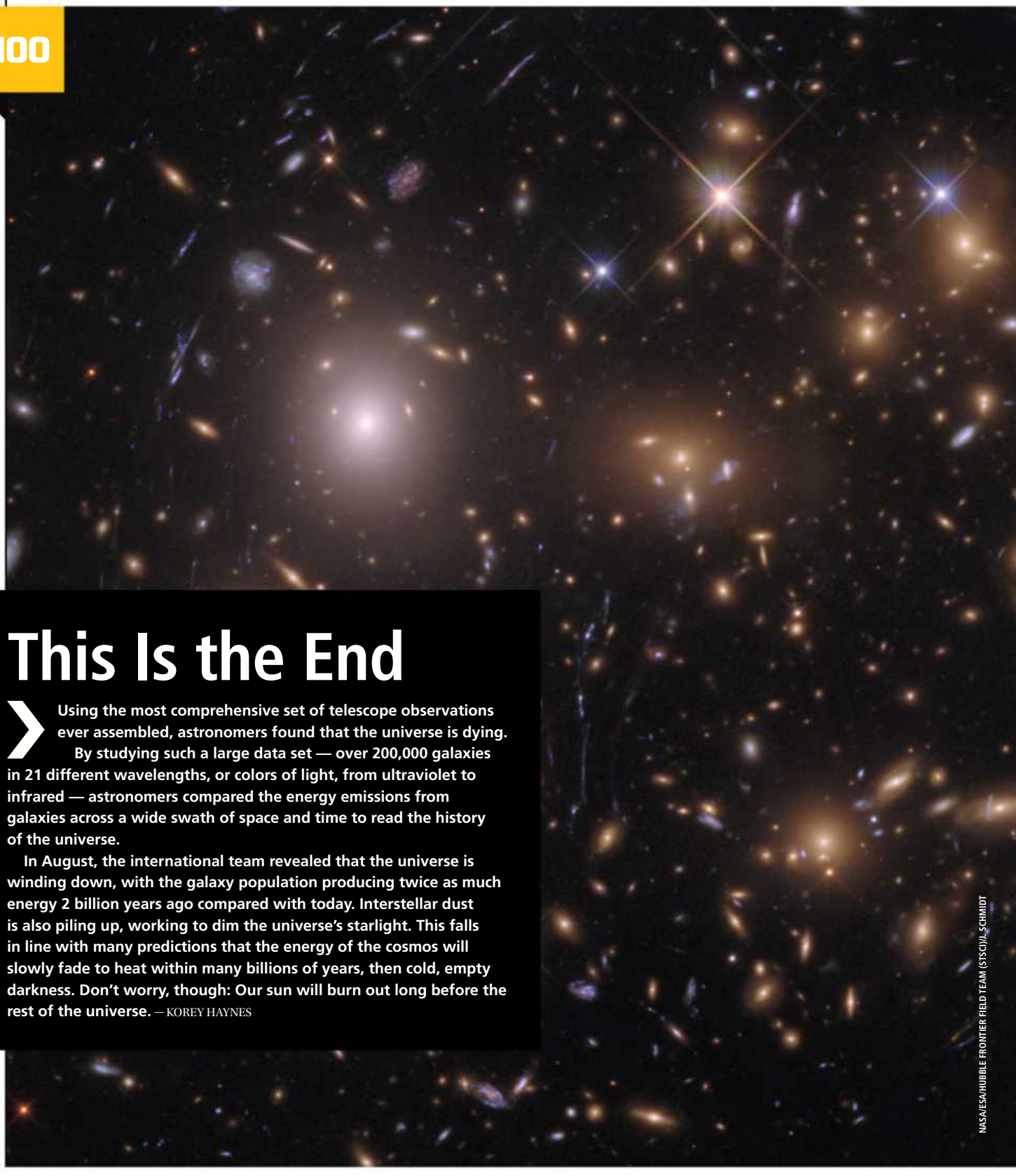

This Is the End

Using the most comprehensive set of telescope observations ever assembled, astronomers found that the universe is dying.

By studying such a large data set — over 200,000 galaxies in 21 different wavelengths, or colors of light, from ultraviolet to infrared — astronomers compared the energy emissions from galaxies across a wide swath of space and time to read the history of the universe.

In August, the international team revealed that the universe is winding down, with the galaxy population producing twice as much energy 2 billion years ago compared with today. Interstellar dust is also piling up, working to dim the universe's starlight. This falls in line with many predictions that the energy of the cosmos will slowly fade to heat within many billions of years, then cold, empty darkness. Don't worry, though: Our sun will burn out long before the rest of the universe. — KOREY HAYNES

NASA/ESA/HUBBLE FRONTIER FIELD TEAM (STSCI)/L. SCHMIDT

The universe's galaxies are only producing half the energy they used to, suggesting an eventual untimely end for the cosmos.

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Fire on the Mountain

A blackened expanse of scorched earth glows red with embers from the Rocky Fire, about 80 miles north of San Francisco. The wildfire burned nearly 70,000 acres in 2015. Years of drought and a century of aggressive fire suppression have rendered vast areas of the West susceptible to large, severe blazes. At the same time, fire seasons are lasting longer around the world, largely because of climate change. (See page 38.) Stuart Palley, who documents wildfires as part of an ongoing project, took this 30-second exposure while the fire raced away from his vantage point. A break in the smoke revealed the moon. No injuries or deaths were reported from the blaze, but it destroyed 43 homes. — ERNIE MASTROIANNI; PHOTO BY STUART PALLEY


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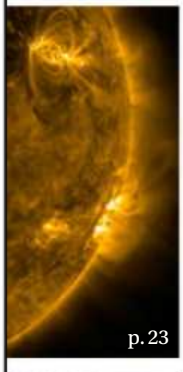
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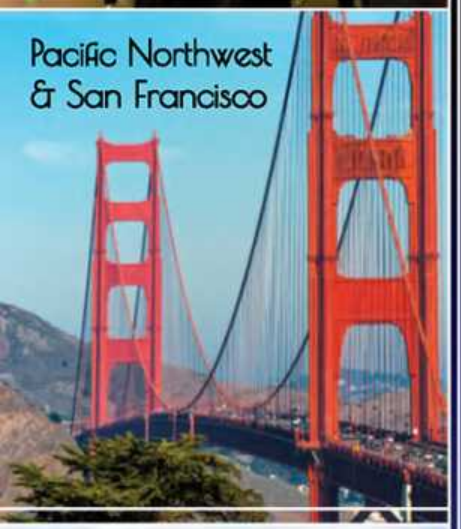
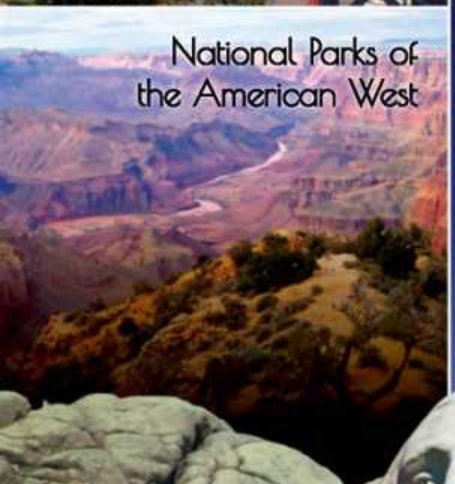




Experience AMERICA'S 2017 TOTAL SOLAR ECLIPSE

August 21, 2017

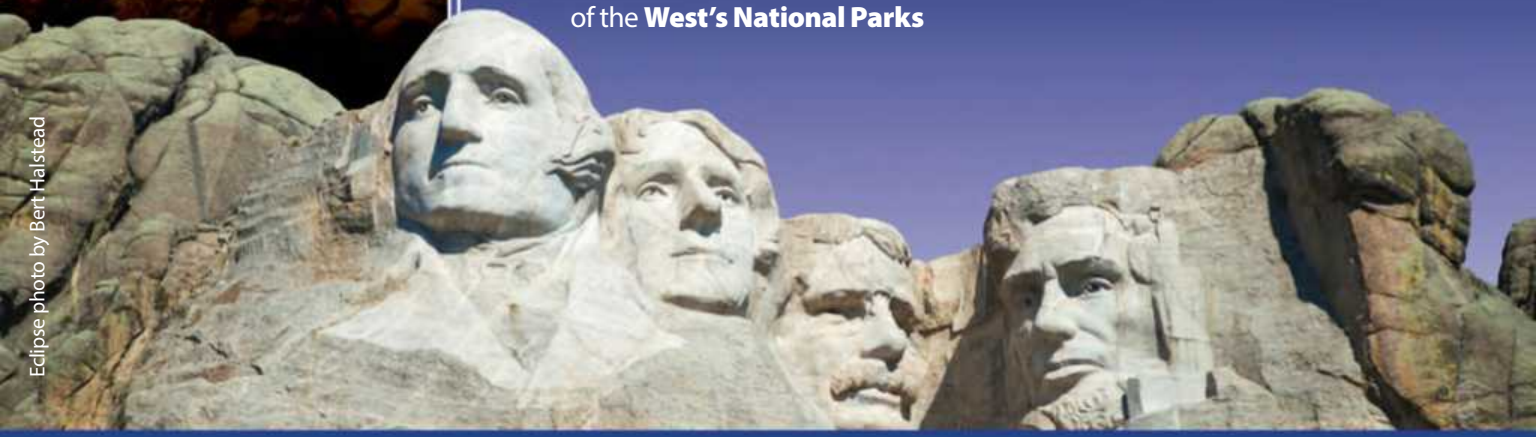
The most awe-inspiring celestial sight is coming to the U.S. for the first time in 26 years. Skywatchers across 12 states can experience darkness at midday as the Moon passes in front of the Sun in a total solar eclipse.

It's an event you don't want to miss, and *Discover* is here to help you make the most of it. Working with TravelQuest International and the editors at our sister magazine, *Astronomy*, we're offering **three exclusive tour packages** that celebrate the many cultural treasures America has to offer.

Surrounding the August 21 total solar eclipse, you can:

- Enjoy jazz, blues, country, and rock 'n' roll in **New Orleans, Nashville, and Memphis**
- Experience the spectacular scenery of the **Pacific Coast from Seattle to San Francisco**
- Journey through the pristine forests and snowcapped mountains of the **West's National Parks**

Eclipse photo by Bert Halstead



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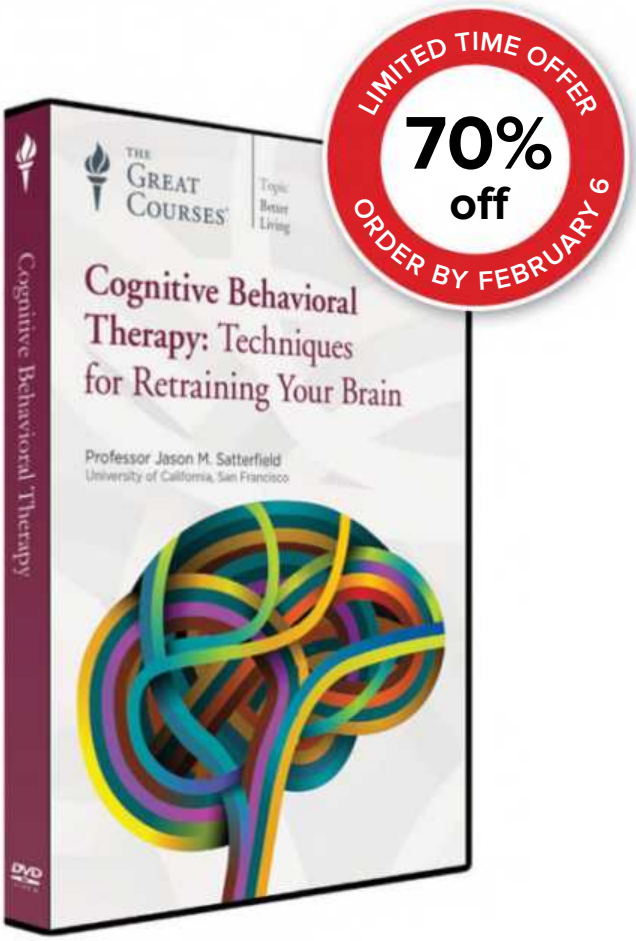

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